NASA CR 114759
DOUGLAS MDC-J4437

(NASA-CR-114759) PARAMETRIC STUDY OF STOL SHORT-HAUL TRANSPORT ENGINE CYCLES AND OPERATIONAL TECHNIQUES TO MINIMIZE COMMUNITY NOISE IMPACT (Douglas Aircraft Co., Inc.) 418 p HC $24.00 CSCL 01C

N74-30428

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G3/02 45841

PARAMETRIC STUDY OF STOL SHORT-HAUL TRANSPORT ENGINE CYCLES AND OPERATIONAL TECHNIQUES TO MINIMIZE COMMUNITY NOISE IMPACT

FINAL REPORT

JUNE REPORT

Prepared Under Contract No. NAS2-6994

for

SYSTEMS STUDIES DIVISION
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MOFFETT FIELD, CALIFORNIA 94035

DOUGLAS AIRCRAFT COMPANY

MCDONNELL DOUGLAS CORPORATION

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FOREWORD

This report covers a study performed for NASA Ames, "Parametric Study of STOL Short-Haul Transport Engine Cycles and Operational Techniques to Minimize Community Noise Impact", under Contract NAS2-6994, Mod. No. 3.

The NASA technical monitor for the study was M. H. Waters, Systems Studies Division, Ames Research Center, California.

The Douglas study team consisted of the following personnel:

Program Manager	:	E. P. Schuld
Acoustics	:	J. P. Crovello
Aerodynamics	:	J. H. Lindley
Airport Evaluation	:	L. H. Quick
Power Plant	:	F. S. LaMar
Weights	:	R. H. Young

The ten-month study, initiated in July 1973, was divided into several phases; i.e., engine cycle studies, propulsion system and acoustic trade studies, aircraft sizing and operational techniques, and community noise impact analyses.

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SYMBOLS & ABBREVIATIONS

A_f	Fan frontal area
AR	Aspect ratio
ARP	Airport reference point
ASKM	Available seat kilometer
ASSM	Available seat statute mile
ATC	Air traffic control
BED	Hanscom Field (Boston)
BPR	Bypass ratio
B-727	Boeing Model 727
C	Centigrade; cost
C_d	Discharge coefficient
C_D	Drag coefficient
C_{D_o}	Zero lift parasitic drag coefficient - zero lift parasitic drag/qS_W
CFM	Cubic feet per minute
C_L	Lift coefficient - lift/qS_W
C.S.D.	Constant speed drive
CTOL	Conventional takeoff and landing
C_μ	Gross thrust coefficient = gross thrust/qS_W
C_v	Nozzle velocity coefficient
dB	Decibel
D	Drag; diameter
DCA	Washington National Airport
DOC	Direct operating cost
EGA	Extra ground attenuation
EPA	Environmental Protection Agency

EBF	Externally-blown-flap
EPNL	Effective perceived noise level
EPNdB	Effective perceived noise level in decibels
F	Thrust force; Fahrenheit
FAA	Federal Aviation Administration
FAR	Federal Air Regulations
FL	Field length
FPR	Fan pressure ratio
fps	Feet per second
ft	Feet
G.A.	General aviation
H	Height of duct flow channel
h_{CRUISE}	Cruise altitude
HP	Horsepower
H.P.	High pressure
IAS	Indicated air speed
in	Inch
K	Kelvin
KE	Kinetic energy
KIAS	Indicated airspeed in knots
kg	Kilogram
kW	Kilowatt
L	Length; left
LAX	Los Angeles International Airport
LFL	Landing field length
L.P.	Low pressure
lb	Pound

m	Meter
M	Mach number
MAC	Mean aerodynamic chord
MDW	Midway Airport (Chicago)
MF	Mechanical flap
MIT	Massachusetts Institute of Technology
mps	Meters per second
N	Newton
NASP	FAA National Airport System Plan
OEW	Operators empty weight
P	Pressure
PL	Payload
PLS	Propulsive lift system
PNdB	Perceived noise level in decibels
PNL	Perceived noise level
Psgr	Passengers
q	Free stream dynamic pressure
Q	Torque; quantity (no. of engines)
QCSEE	Quiet Clean STOL Experimental Engine Study
QRPLS	Quick response powered lift system
R	Rankine; right
Rwy	Runway
s	Second
SAE	Society of Automotive Engineers
S_W	Wing area
SLS	Sea level static
SNA	Orange County (Calif.) Airport

st mi	Statute miles
STOL	Short takeoff and landing
t	Time; thickness
T	Temperature
t/c	Thickness ratio
TOFL	Takeoff field length
TOGW	Takeoff gross weight
T/W	Thrust-to-weight ratio
U.S.A.F.	United States Air Force
U.S.G.S.	United States Geological Survey
V	Velocity
V_R	Relative velocity (primary exhaust velocity - V_o)
V_1	Decision speed
V_2	Speed at end of gear retraction, with critical engine failed
W	Weight; watts
w	Mass flow
W/S	Wing loading
α	Angle of attack
γ	Flight path angle
δ	Pressure relative to sea level standard
δ_F	Flap angle
η_{fan}	Fan efficiency
Θ	Aircraft pitch attitude; relative absolute temperature
$\dot{\Theta}$	Aircraft pitch rate

Λ	Sweep angle
λ	Taper ratio
μ	Coefficient of friction
ν	Static thrust turning angle
τ	Ratio of gross thrust to takeoff gross thrust
ϕ	Aircraft roll attitude

Subscripts

A	Air, airplane trimmed
CR	Cruise
DUCT	Engine fan exhaust duct
PRI	Engine core exhaust duct
T.E.	Trailing edge
T.O.	Takeoff
a	Air
am	Ambient
aver	Average
f	Fuel; fan
g	Gross
max	Maximum
n	Net
o	Free stream, standard sea level
r	Ram
t	Total
ult	Ultimate
0, 2, 4, 28	Engine station position

STOL Aircraft Model Designation

E - 150 - 3000

E = EBF   Passenger   Field Length
M = MF   Payload   (feet)

Engine Designation

12.8/1.32

Bypass Ratio   Fan Pressure Ratio

1.0 SUMMARY

The main goal of this study was to investigate the effect of aircraft operational techniques in the terminal area on community noise impact of future short-haul aircraft. One mechanical-flap (MF) aircraft and one externally-blown-flap (EBF) aircraft were used to study the noise impact at four U.S. airports: Hanscom Field (Boston); Washington National; Midway (Chicago); and Orange County (California). The EBF aircraft was the final design E-150-3000 aircraft developed during the NASA STOL Systems Study, Reference 1.

With the exception of Washington National (DCA), the study showed that a reduction of approximately 40 percent in the number of people highly annoyed (as defined in the study) can be obtained by using these operational techniques. At DCA the number of people highly annoyed using the standard procedure was quite low, but it is significant that the minimum-impact case for Runway 36 reduced the number of people highly annoyed to zero by using a power cutback and a turning departure path. The evaluation procedures and methodology developed in this study represents an advance in acoustical state-of-the-art and should provide an effective and useful tool for determining aircraft noise impact upon the airport community.

The MF aircraft was developed by a series of studies which began with a comparison of 150-passenger, 2- vs 4-engine configurations designed for a 3000-foot field length. The 2-engine configuration proved to be slightly superior. The study progressed by comparing 2-engine MF aircraft designed for 3000-foot and 4000-foot field lengths. Concurrently, an acoustic/engine cycle trade study was conducted on engines with fan pressure ratios of 1.32, 1.45, and 1.57 using takeoff sideline noise as the acoustic criterion. These engines were examined with no acoustic treatment (hardwall)

and with nacelle wall treatment. The trade study included generation of uninstalled performance and weight estimates, preparation of installation drawings, calculation of installed engine performance, calculation of takeoff noise levels, and estimation of engine prices. At the outcome of the MF aircraft studies, it was concluded that an M-150-4000 aircraft with twin 1.57 FPR engines (nacelle wall treatment) should be used in the community noise impact phase of the study. The M-150-4000 and M-150-3000 aircraft had essentially the same noise impact, but the DOC of the M-150-3000 aircraft was approximately 18 percent higher and the mission fuel 24 percent greater.

A study was conducted to determine the sensitivity of the NASA STOL Systems Study final design E-150-3000 aircraft to changes in wing sweep and thickness ratio. During the NASA STOL Systems Study, it was determined that this aircraft was relatively insensitive to aspect ratio and that AR = 8 was near optimum. Similarly, it was found that wing sweep and wing thickness had little effect and that changing to an optimum wing (primarily a reduction in wing sweep) would result in approximately a one to two percent reduction in DOC. The insensitivity to wing geometry is partly due to the engine being selected for a field length and sideline noise requirement rather than for a cruise speed requirement.

A Douglas-developed computer program was used to generate takeoff and landing flight profiles for use in the noise impact studies. In this program, parameters can be varied to determine their effect on the flight path. The parameters varied were:

<u>Takeoff</u>

a) Flap retraction altitude
b) Flap retraction rate
c) Thrust cutback altitude
d) Thrust cutback amount
e) Amount of turning

Landing

a) Glide slope angle
b) Change in slope angle - two segment approach
c) Flap extension rate

The above program develops flight path data which is input to a Douglas-developed acoustic computer program which calculates noise contours and community noise impact.

The acoustic program uses predicted EPNL vs distance information together with the flight profile data to compute single-event EPNL contours as well as the total area enclosed by each contour. To evaluate the community noise impact, census data is required for each airport examined, and an annoyance factor, in terms of the percent of people highly annoyed, is computed as a function of EPNL. By definition, the summation of the annoyance factor times the population is the number of people highly annoyed in the vicinity of the airport in question.

A standard operational technique was established for both the MF and EBF aircraft. A low-impact operational procedure was then obtained as a result of parametric studies of the effects on noise impact of varying operational parameters, such as, flap retraction height and rate, and thrust cutback height and amount. These studies assumed a uniform population distribution. By superimposing the low-impact contour on a standard 7.5 minute U.S.G.S. topographical map with an overlay showing census tract population, it was possible to optimize or "fine-tune" the low-impact operational procedure to the specific airport community by varying takeoff flight techniques. The contour was shaped by varying the level of power cutback, cutback altitude and turn altitude and amount. Turns were made to follow

waterways, parks, railroads, etc., to avoid highly populated and noise sensitive areas. The final result was a minimum-impact procedure. No detailed optimization was made for the approach procedure since the size of the low-impact approach contour using a decelerating approach technique was found to be minimal.

Also studied (at Midway Airport) was the effect of oversizing by 10 percent the engines on the E-150-3000 aircraft. The objective was to reduce the noise impact by having steeper climb angles up to the point of thrust cutback. This oversized case resulted in an additional 8 percent reduction in the number of people highly annoyed at Midway, employing the same operational techniques used for the non-oversized case.

The typical noise impact reductions achieved by operational techniques for both aircraft were studied. However, the noise impact reduction for the M-150-4000 aircraft was less than that for the E-150-3000 aircraft. This is mainly due to the higher sideline noise produced by the M-150-4000 aircraft which increased the width of the noise contours.

The study methods used herein for aircraft operational noise alleviation provide a tool which can be used to help establish terminal area flight procedures. Although it was not applied in this study, the capability also exists to compare operational flight procedures on the basis of fuel consumption as well as noise impact to determine minimum energy procedures in the terminal area.

The accuracy is limited by the accuracy of the noise-impact prediction methodology, the validity of the noise annoyance function, and the census data base. Much work remains to be done to develop more accurate aircraft noise prediction methods, to improve and validate methods for predicting community response, and to standardize airport noise evaluation methodology.

2.0 INTRODUCTION

Past studies have shown the benefits of low fan pressure ratio engines and the use of acoustically-treated nacelles for reducing the noise generated by aircraft. This program used a FPR = 1.25 engine on the final design E-150-3000 aircraft from the NASA STOL Systems Study (Reference 1) and a FPR = 1.57 engine on a M-150-4000 aircraft. Both had acoustical treatment on the nacelle walls; however, the nacelle for the FPR = 1.57 engine was designed for aerodynamic performance and neither the inlet nor fan exhaust ducts were extended for further noise reduction. To reduce the community noise impact, this study investigated the effects of varying the aircraft operating procedures in the terminal area.

The objectives of this study were to:

- Determine an optimum engine cycle for a short-haul mechanical-flap airplane considering tradeoffs between acoustics, performance, and economics.
- Investigate aircraft operational techniques in the terminal airport area to minimize the noise impact on the community.
- Evaluate the noise impact of the study aircraft in four representative airport communities.

The study was conducted in four major steps as shown in Figure 2-1.

Aircraft trade studies were performed to select an optimum MF aircraft configuration, as well as to determine the effect of wing geometry and oversized engines on the EBF configuration.

For the acoustic trade study, three engine cycles, with and without acoustic treatment, were used to size the MF aircraft for two field lengths

STUDY PLAN

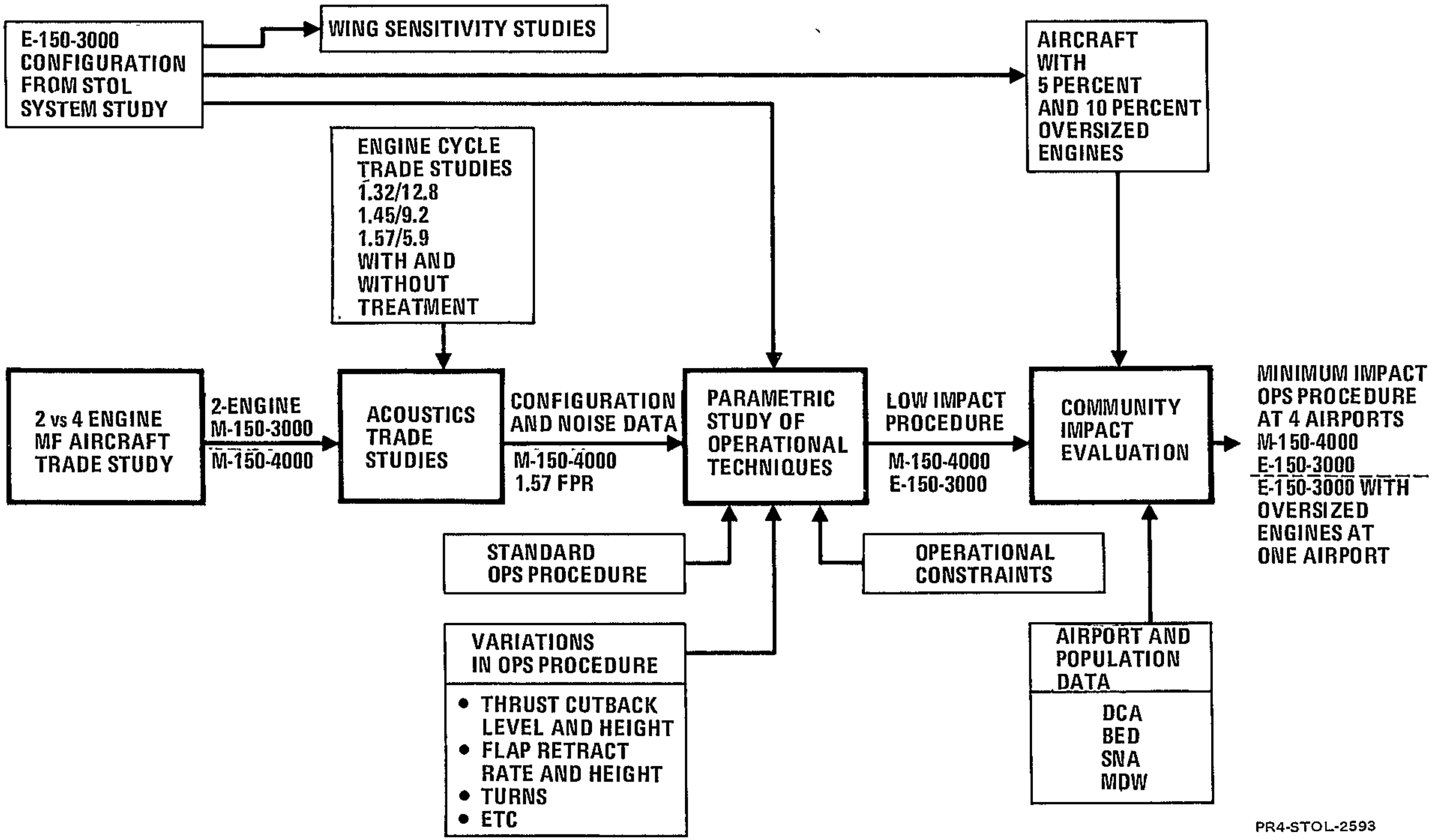

FIGURE 2-1.

to form a matrix of twelve aircraft. From this study, the M-150-4000 aircraft was selected for further community noise impact analyses.

The parametric study of operational techniques was performed to determine the effect on community noise of various operational techniques for EBF and MF aircraft assuming a uniform population distribution. Low-impact procedures and noise contours resulted from these studies which were used as a starting point for the evaluation of community impact.

For the community impact evaluation, the aircraft operational techniques were optimized at selected airports (using census population data) to develop a minimum-impact procedure for a particular runway. As shown in Figure 2-1, the minimum-impact procedure was developed for the EBF and MF aircraft at four study airports and for the EBF with oversized engines at one airport.

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3.0 AIRCRAFT CONFIGURATION TRADE STUDIES

3.1 Mechanical Flap (MF) Aircraft Configuration Study

Current short-haul aircraft such as the McDonnell Douglas DC-9 and Boeing 737 are twin-engine configurations. A twin-engine configuration will tend to have lower initial engine cost, lower engine maintenance costs and increased dispatch reliability as compared to a four-engine configuration. On the other hand, engine-out performance requirements dictate higher total installed engine thrust for the twin. As design field length is reduced to that normally associated with STOL aircraft, the engine-out performance becomes increasingly significant resulting in a twin-engine configuration that is much heavier than one with more than two engines.

3.1.1 Twin vs Four Engine Comparison - A trade study was conducted on a 3000-foot (914 m) field length mechanical-flap aircraft to determine whether it would have lower direct operating costs as a two or a four-engine configuration. It was assumed that if the trade study showed a twin-engine configuration to be better at 3000-foot (914 m) field lengths it would also be better at 4000 feet (1219 m). If a four-engine configuration was superior at 3000 feet (914 m) then the same type of trade study would be necessary for the 4000-foot (1219 m) field length configurations.

Two aircraft were sized, a twin-engine and four-engine design as shown in Figures 3-1 and 3-2. Both aircraft are high wing configurations with engines mounted under the wings and are designed to carry 150 passengers over a 575 statute mile (926 km) stage length. Fairly long engine pylons allow elimination of flap cutouts, and two-segment tracked-motion flaps provide efficient low speed aerodynamic performance. Aerodynamic character-

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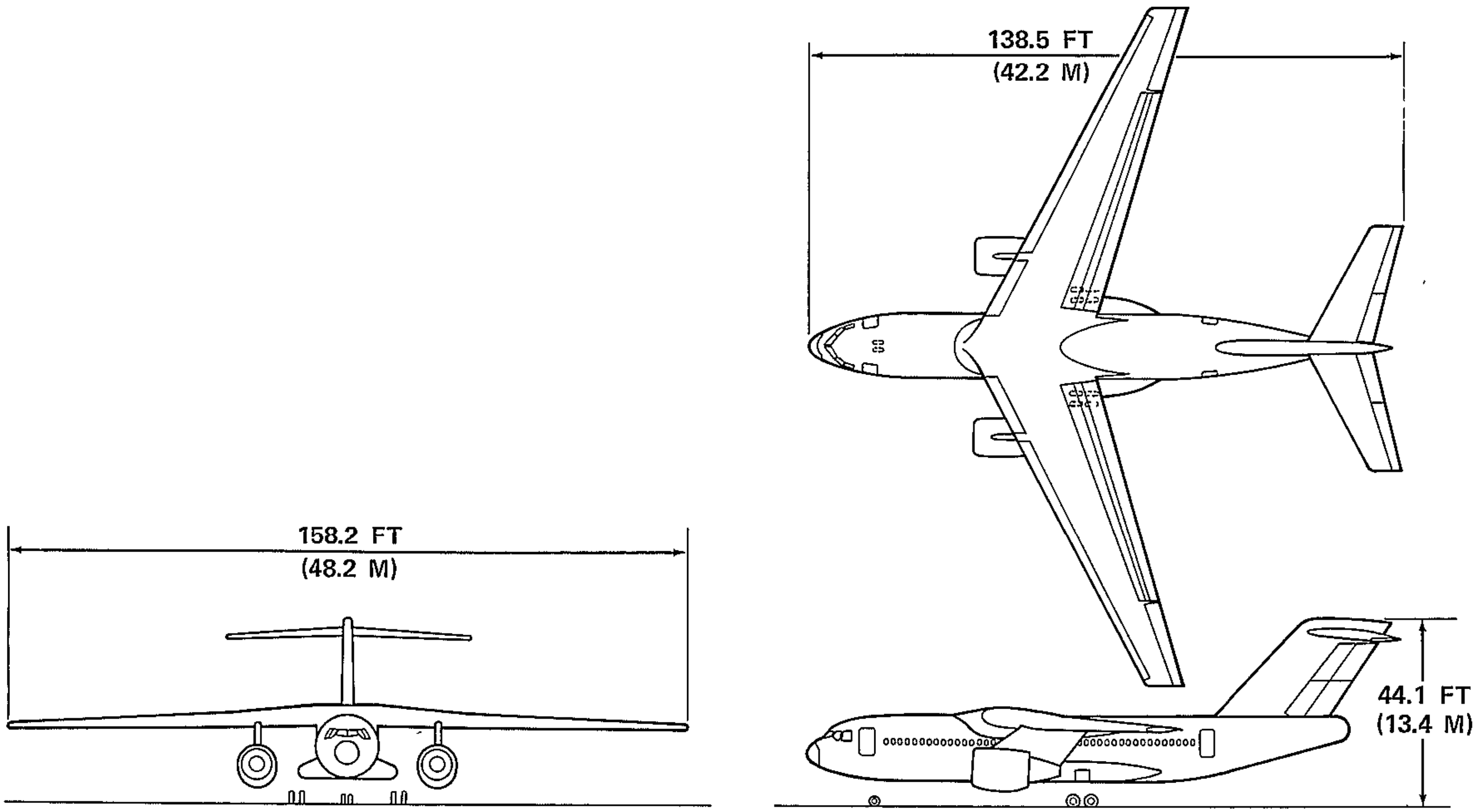
GENERAL ARRANGEMENT

M-150-3000 — TWO PD287-6 ENGINES



PR3-STOL-2045

FIGURE 3-1.

GENERAL ARRANGEMENT

M-150-3000 — FOUR PD287-6 ENGINES

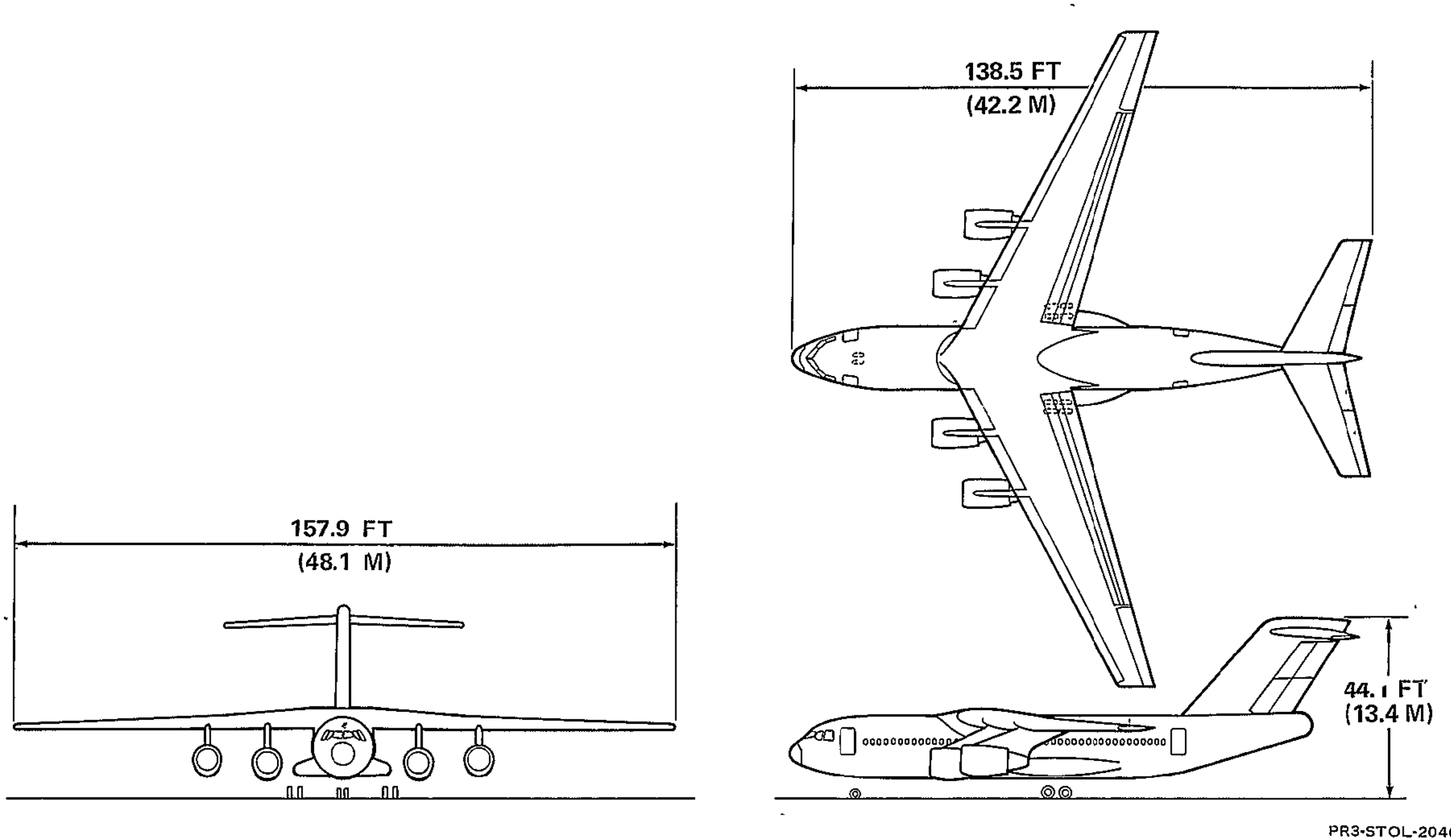


FIGURE 3-2.

istics are presented in Appendix A.2. Allison PD287-6 engines (1.32 FPR),as used in the acoustic trade study of the NASA Short-Haul STOL System Study (Reference 1), were utilized.

Aircraft sizing was performed in accordance with the ground rules and methods described in Appendix A.1. The procedure involves calculating takeoff and landing performance to determine wing loading (W/S) and thrust-to-weight ratio (T/W) combinations that produce a 3000-foot (914 m) field length. These W/S and T/W combinations together with parametric weight, drag, engine performance and tail sizing data are combined with the mission requirements to define the aircraft characteristics such as TOGW, wing area and engine size.

The resulting sizing charts for the two aircraft are shown in Figure 3-3. The twin-engine configuration design point was selected at a W/S = 60.3 lb/ft^2 (294 kg/m^2)and T/W = 0.381 where landing and takeoff field length performance are equally critical. Landing field length performance is not a function of T/W for an unpowered high-lift system so the 3000-foot (914 m) field length requirement restricts W/S to values less than or equal to 60.3 lb/ft^2 (294 kg/m^2). The T/W value of 0.381 was selected on the basis of minimum DOC and weight rather than to achieve a given cruise Mach Number. Cruise Mach Number is a fallout from the sizing process. An increase in T/W will increase both DOC and TOGW.

The four-engine configuration sizing is somewhat more complex. As in the two-engine case, landing performance restricts the W/S to values no greater than 60.3 lb/ft^2 (294 kg/m^2). Takeoff and landing are equally critical at W/S = 60.3 lb/ft^2 (294 kg/m^2) and T/W = 0.289. Minimum DOC occurs, however, at a T/W = 0.350 on the landing critical line. The DOC is lower at this T/W than at the point where takeoff and landing are equally critical because the

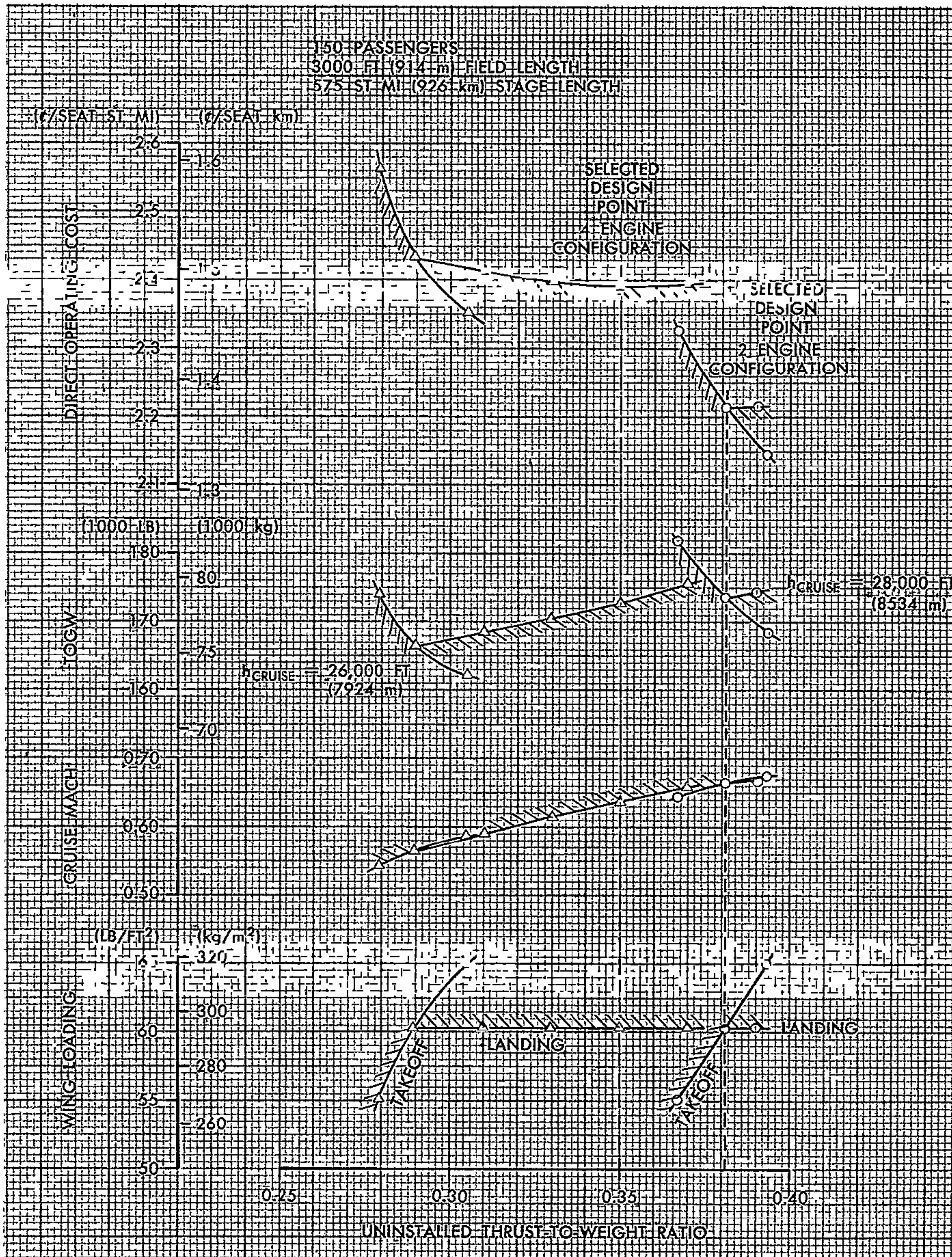


FIGURE 3-3. MECHANICAL FLAP CONFIGURATION STUDY—TWO VS FOUR ENGINE SIZING COMPARISON

gross weight increase is more than offset by the increase in cruise Mach number. Selection of the sizing point was made on the basis of minimum DOC.

A summary comparing the performance characteristics of the two aircraft is presented in Table 3-1. The four-engine configuration has a slightly lower gross weight (0.3%) and lower fuel consumption (2.5%) than the two-engine aircraft but DOC is 8 percent higher. The increased DOC is the result of higher total engine costs and engine maintenance. On the basis of this DOC difference, the two-engine configuration was selected for parametric aircraft sizing during the acoustic trade study for field lengths of both 3000 and 4000 feet (914 and 1219 m).

3.1.2 Sensitivity to Engine Costs - A sensitivity analysis was performed to assess the impact of engine cost on the trade study results. The DOC values presented in the sizing chart and performance summary were based on an engine cost curve used in the STOL Short-Haul Study (Reference 1). A revised curve has been derived (Section 4.2.6), based on a statistical study of engine prices, which has a greater variation of cost with thrust. The two cost curves are compared in Figure 3-4.

Use of the revised cost curve, as illustrated in Table 3-2, reduces the DOC difference between the two and four-engine configurations from 8 percent to 6 percent. The assumption that engines would be produced exclusively for the STOL aircraft, i.e., there would be only half as many engines produced for the twin configuration as for the four-engined configuration, would reduce the DOC difference to just over one percent. The twin-engined aircraft still has lower direct operating costs but differences are minimal. For a production design, the configuration choice would be greatly influenced by the thrust sizes of available engines.

TABLE 3-1

TWO Vs FOUR ENGINE MECHANICAL-FLAP STOL AIRCRAFT CONFIGURATION STUDY

PERFORMANCE SUMMARY

150 Passengers, 3000-ft (914 m) Field Length

PD287-6 Engines, Wall Acoustic Treatment

		2-Engine Configuration	4-Engine Configuration
Design TOGW	lb (kg)	173,550 (78,720)	172,900 (78,430)
Wing Area	ft^2 (m^2)	2,878 (267)	2,867 (266)
Thrust/Engine	lb (N)	33,060 (147,100)	15,130 (67,300)
Wing Loading	lb/ft^2 (kg/m^2)	60.3 (294)	60.3 (294)
Thrust-to-Weight Ratio		0.381	0.350
OEW	lb (kg)	125,260 (56,820)	125,110 (56,750)
Wing Aspect Ratio		8.7	8.7
Cruise Mach Number		0.66	0.64
Cruise Altitude	ft (m)	28,000 (8,500)	26,000 (7,900)
DOC @ 575 st. mi. (926 km)	¢/ASSM (¢/ASKM)	2.21 (1.37)	2.39 (1.48)
Block Fuel @ 575 st. mi. (926 km)	lb (kg)	13,390 (6070)	13,030 (5910)

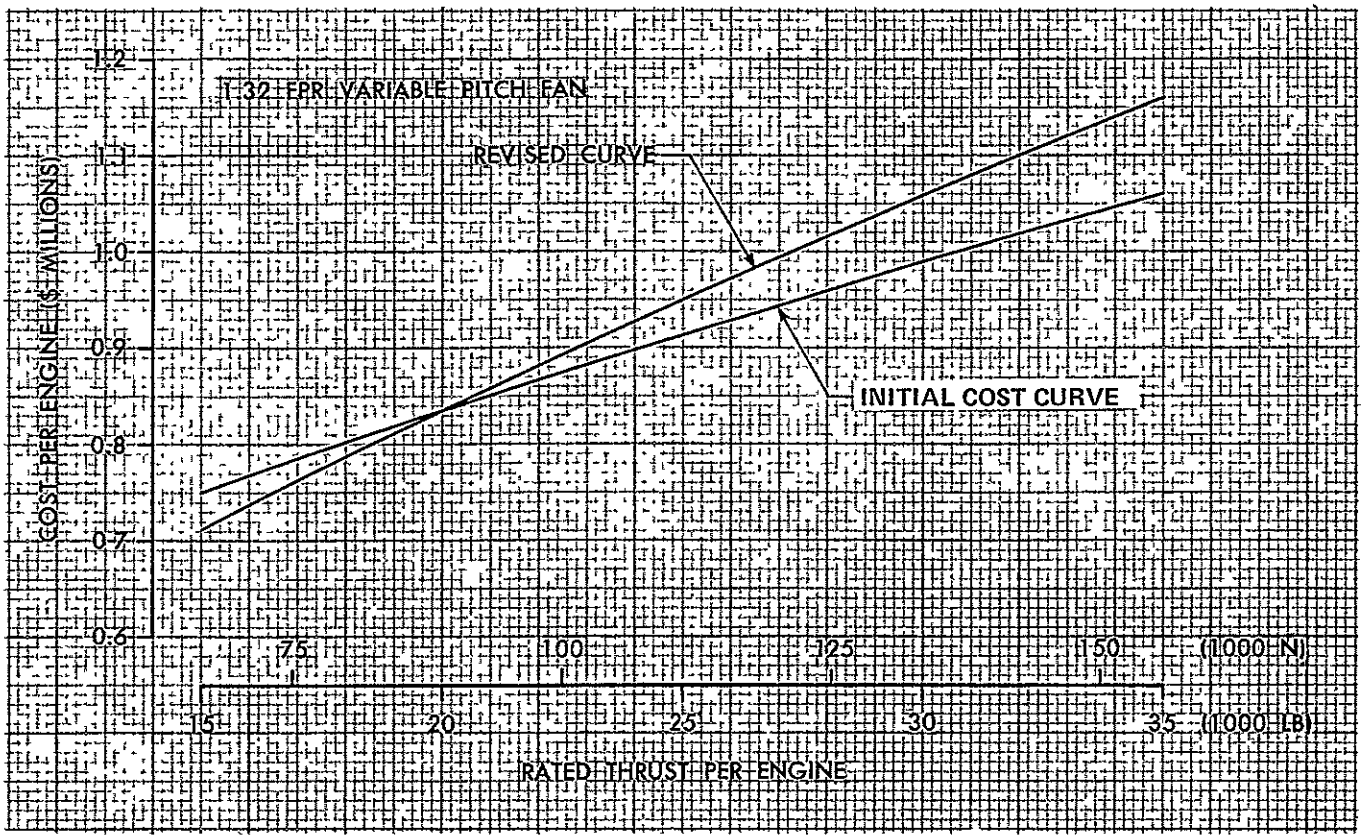


FIGURE 3-4. ENGINE COST vs THRUST

TABLE 3-2

EFFECT OF ENGINE COST ON TRADE STUDY RESULTS
DOC @ 575 Statute Miles (926 km) in ¢/ASSM (¢/ASKM)

	2 Engine Configuration	4 Engine Configuration
1. Initial cost curve (base case)	2.21 (1.37)	2.39 (1.48)
2. DAC revised cost curve	2.24 (1.39)	2.37 (1.47)
3. Assume production run for 2-engine configuration engines is half that for 4-engine configuration engines (1.35 x costs from 2).	2.34 (1.45)	2.37 (1.47)

3.2 Externally-Blown-Flap Aircraft Wing Geometry Sensitivity

A study was completed to determine the sensitivity of a 150-passenger, 3000-foot (914 m) field length externally-blown-flap STOL aircraft to independent variations in wing geometry; i.e., aspect ratios, average wing thickness ratios and wing sweeps. The purpose of the study was to evaluate the sensitivity of wing geometry on aircraft sizing rather than to determine the optimum geometry for this specific aircraft. The sizing calculations were performed in a manner consistent with the methods described in Reference 1, Appendix B of Volume II. The sized aircraft presented below are all at wing loading and thrust-to-weight ratio combinations for balanced takeoff and landing field length. The E-150-3000 Final Design Aircraft with 1.25 FPR engines, as described in Volume II of Reference 1, was used as the basepoint for the study.

3.2.1 Aspect Ratio Study - The choice of wing aspect ratio is based on a tradeoff between increased aerodynamic efficiency and increased wing structural weight associated with an increase in aspect ratio. The influence of aspect ratio on the sizing of a 150-passenger, 3000-foot (914 m) field length externally-blown-flap STOL aircraft was examined in the NASA STOL Short-Haul System Study (Reference 1) and is summarized below.

High-lift aerodynamic data for aspect ratios of 7, 8 and 9 were used in determining wing loading and thrust-to-weight ratio combinations that would result in a 3000-foot (914 m) field length capability. These wing loading and thrust-to-weight combinations, in conjunction with parametric weight and drag data for each aspect ratio, were used for aircraft sizing. The primary effect of increasing aspect ratio on aircraft drag is to decrease induced drag.

The resulting aircraft for the three aspect ratios are summarized in Table 3-3. Figure 3-5 graphically depicts the influence of aspect ratio on aircraft sizing. The figure shows minimum direct operating cost occurs at an aspect ratio of 8. However, the variation of direct operating cost with aspect ratio is very small, being less than 0.5 percent for a variation in aspect ratio from 7 to 9.

3.2.2 Wing Thickness Ratio Study - The effects on aircraft sizing of increasing wing thickness ratio are primarily due to decreasing wing structural weight and increasing parasite and compressibility drag. Induced drag and low speed aerodynamic efficiency are not significantly affected by varying wing thickness ratio. Accordingly, the same wing loading and thrust-to-weight ratio combinations, for a 3000-foot (914 m) field length capability were used in sizing aircraft with average wing thickness ratios of .10, .1375 and .16. Separate parametric weight data and parasite and compressibility drag estimates were used for sizing the aircraft with each of the three average wing thickness ratios. These aircraft are summarized in Table 3-4. The effect of varying average wing thickness ratio is shown in Figure 3-6. The figure shows minimum direct operating cost occurred at an average wing thickness ratio of .15. However, variation of average wing thickness ratio over the range examined resulted in a maximum change in direct operating cost on the order of one percent.

3.2.3 Wing Sweep Study - Increasing wing sweep affects aircraft sizing by decreasing parasite and compressibility drag, increasing induced drag, degrading low-speed aerodynamic efficiency and increasing wing structural weight. Effects on aircraft sizing due to wing sweep variation were determined by sizing aircraft for wing sweeps of 5.6, 15 and 25 degrees (0.10, 0.26, and 0.44 rad). High-lift data for each wing sweep were used to determine wing

Table 3-3

ASPECT RATIO STUDY AIRCRAFT

Externally-Blown-Flap Configuration

$\lambda = .3,\ t/c_{avg} = .1375,\ \Lambda = 25°\ (.44\ \text{rad})$

Aspect Ratio		7		8		9	
Passengers		150		150		150	
Design Field Length	ft (m)	3,000	(914)	3,000	(914)	3,000	(914)
Engine		PD287-3		PD287-3		PD287-3	
TOGW	lb (kg)	149,900	(68,000)	149,000	(67,600)	149,400	(67,800)
Wing Area	ft^2 (m^2)	1,521	(141.3)	1,461	(135.7)	1,448	(134.5)
Thrust/Engine	lb (N)	18,860	(83,890	18,260	(81,220)	17,820	(79,270)
W/S	lb/ft^2 (kg/m^2)	98.5	(481)	102.0	(498)	103.2	(504)
T/W		0.504		0.490		0.477	
OEW	lb (kg)	102,920	(46,680)	102,610	(46,540)	103,390	(46,900)
Cruise Mach Number		0.70		0.69		0.69	
Cruise Altitude	ft (m)	26,000	(7,925)	26,000	(7,925)	26,000	(7,925)
D.O.C. @ 575 st mi (926 km)	¢/ASSM (¢/ASKM)	2.085	(1.295)	2.076	(1.290)	2,081	(1.293)

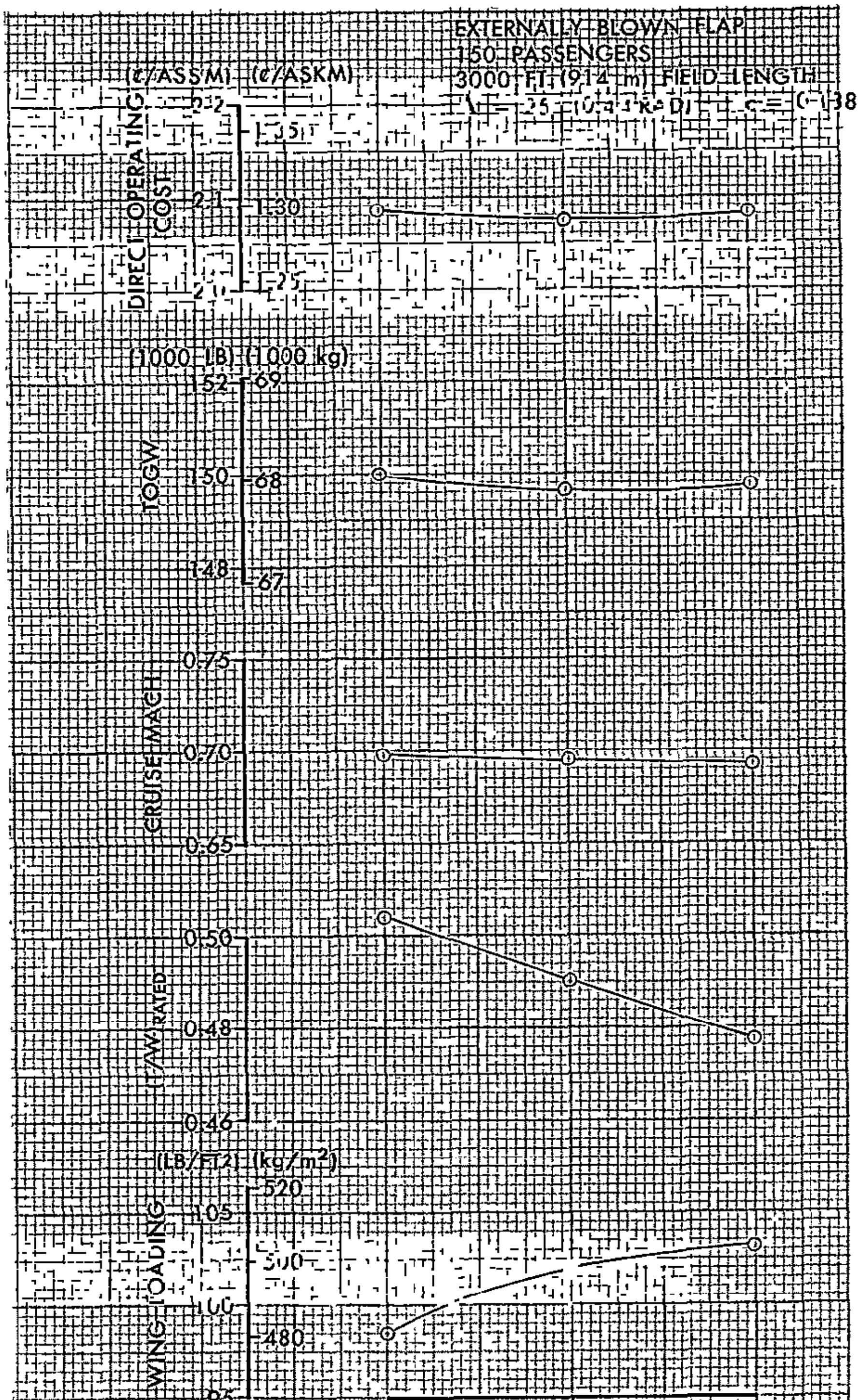


FIGURE 3-5. EFFECT OF ASPECT RATIO ON AIRCRAFT SIZING FOR EXTERNALLY BLOWN FLAP AIRCRAFT

TABLE 3-4

WING THICKNESS RATIO STUDY AIRCRAFT

EXTERNALLY-BLOWN-FLAP CONFIGURATION

$\lambda = .3, \quad AR = 8, \quad \Lambda = 25°$ (.44 rad)

Average Wing Thickness Ratio		.10	.1375	.16
Passengers		150	150	150
Design Field Length	ft (m)	3000 (914)	3000 (914)	3000 (914)
Engine		PD287-3	PD287-3	PD287-3
TOGW	lb (kg)	152,300 (69,100)	149,000 (67,600)	148,100 (67,200)
Wing Area	ft^2 (m^2)	1493 (138.7)	1461 (135.7)	1452 (134.9)
Thrust/Engine	lb (N)	18,660 (83,000)	18,260 (81,220)	18,140 (80,690)
W/S	lb/ft^2 (kg/m^2)	102.0 (498)	102.0 (498)	102.0 (498)
T/W		0.490	0.490	0.490
OEW	lb (kg)	105,710 (47,950)	102,610 (46,540)	101,630 (46,100)
Cruise Mach Number		0.70	0.69	0.69
Cruise Altitude	ft (m)	26,000 (7925)	26,000 (7925)	26,000 (7925)
D.O.C. @ 575 st. mi. (926 km)	¢/ASSM (¢/ASKM)	2.099 (1.304)	2.076 (1.290)	2.074 (1.289)

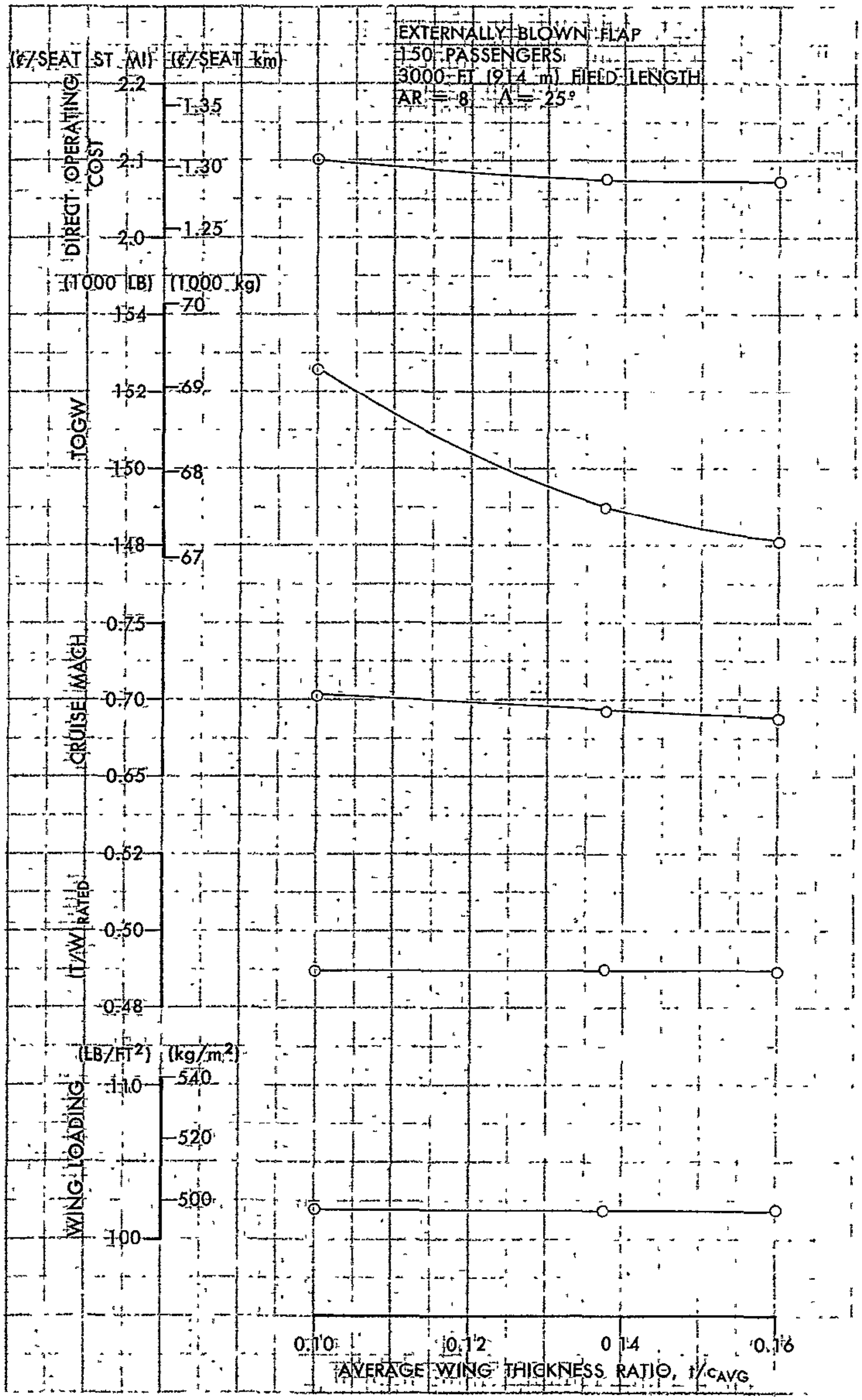


FIGURE 3-6. EFFECT OF WING THICKNESS RATIO ON AIRCRAFT SIZING FOR EXTERNALLY BLOWN FLAP AIRCRAFT

loading and thrust-to-weight ratio combinations for 3000-foot (914 m) field length capability. The wing loading and thrust-to-weight ratio combinations for balanced takeoff and landing field length capability along with parametric weight data and high-speed drag estimates for each wing sweep were used in sizing the aircraft.

The resultant aircraft are summarized in Table 3-5. Figure 3-7 shows the effect of varying wing sweep on the aircraft sizing. The variation of direct operating cost with wing sweep is shown to be less than one percent for a variation of wing sweep from 5.6° to 25° (0.10 to 0.44 rad). The lowest DOC was obtained with the lowest wing sweep since the high thrust lapse of the 1.25 FPR engines prohibit high cruise speeds.

It should be noted that the 5.6° (0.10 rad) sweep results in a straight rear wing spar and a flap hinge line perpendicular to the fuselage and consequently simple flap hinge fittings. Reduction of wing sweep below 5.6° (0.10 rad) would not be expected to produce further economic benefits.

3.2.4 <u>Conclusions</u> - Direct operating cost (DOC) is not particularly sensitive to aspect ratio, wing thickness ratio or wing sweep for the E-150-3000 aircraft with 1.25 FPR engines. This conclusion is valid when the aircraft is sized by the design field length requirement rather than for a specific cruise speed capability. Sizing for a given cruise Mach Number would cause DOC to be more sensitive to wing geometry.

An aspect ratio of 8, wing thickness ratio of 0.15 and a wing sweep of 5.6° (0.10 rad) appear to be near optimum wing geometry for this specific aircraft based on minimizing DOC at the design range. The resulting reduction in DOC compared to the final design E-150-3000 aircraft from the NASA STOL Short-Haul System Study would only be about one percent.

TABLE 3-5

WING SWEEP STUDY

EXTERNALLY-BLOWN-FLAP CONFIGURATION

$\lambda = .3$, AR = 8, t/c = .1375

Wing Sweep	deg (rad)	5.6 (.10)	15 (.26)	25 (.44)
Passengers		150	150	150
Design Field Length	ft (m)	3000 (914)	3000 (914)	3000 (914)
Engine		PD287-3	PD287-3	PD287-3
TOGW	lb (kg)	144,300 (65,400)	146,000 (66,200)	149,000 (67,600)
Wing Area	ft^2 (m^2)	1,374 (127.6)	1,391 (129.2)	1,461 (135.7)
Thrust/Engine	lb (N)	16,950 (75,400)	17,600 (78,290)	18,260 (81,220)
W/S	lb/ft^2 (kg/m^2)	105.0 (513)	105.0 (513)	102.0 (498)
T/W		0.470	0.482	0.490
OEW	lb (kg)	98,330 (44,600)	99,780 (45,260)	102,610 (46,540)
Cruise Mach Number		0.67	0.68	0.69
Cruise Altitude	ft (m)	25,000 (7,620)	25,000 (7,620)	26,000 (7,925)
D.O.C. @ 575 st. mi. (926 km)	¢/ASSM (¢/ASKM)	2.057 (1.278)	2.061 (1.281)	2.076 (1.290)

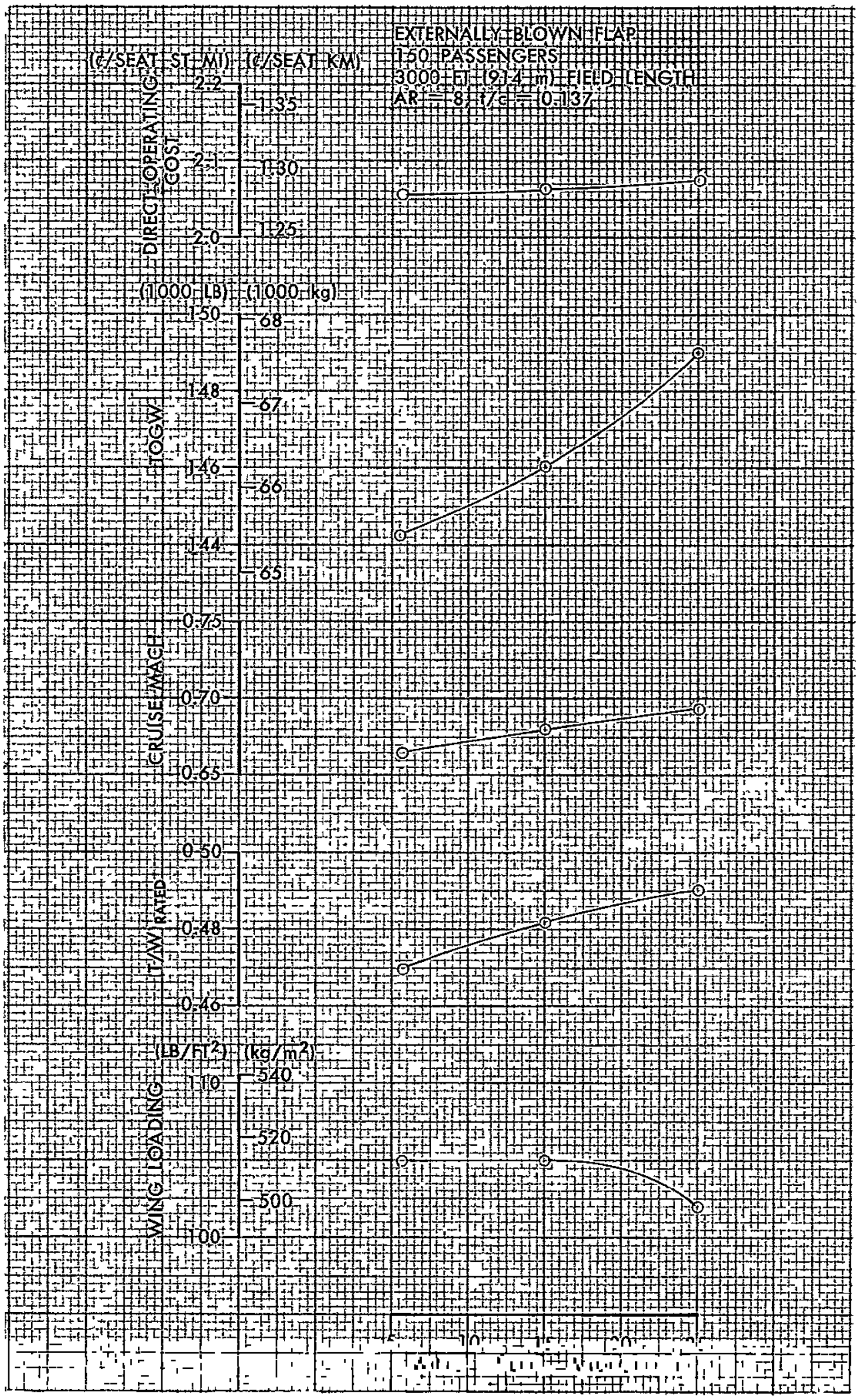


FIGURE 3-7. EFFECT OF WING SWEEP ON AIRCRAFT SIZING FOR EXTERNALLY BLOWN FLAP AIRCRAFT

3.3 Externally-Blown-Flap Aircraft with Oversized Engines

A trade study was conducted to determine if increasing the engine thrust size over that required to meet takeoff and landing field length requirements would reduce community noise impact for a short-haul aircraft. Increasing engine size tends to increase sideline and approach noise but the increased climb gradient associated with higher aircraft thrust-to-weight ratio may result in a significant reduction in takeoff noise impact.

The E-150-3000 final design aircraft from the NASA Short-Haul System Study (Reference 1) was chosen as a basepoint. This aircraft was sized on the basis of minimum DOC which occurs at the intersection of the landing and takeoff critical lines, i.e., takeoff field length = landing field length = 3000 feet (914 m), as illustrated in Figure 3-8. Two additional aircraft were sized having approximately 5 and 10 percent higher thrust engines than the base aircraft. To minimize DOC penalties, design points for these two additional aircraft were selected on the landing critical line, i.e., increasing wing loading as engine thrust size is increased to maintain a 3000-foot (914 m) landing field length. As can be seen in Table 3-6, there is essentially no increase in DOC associated with the use of larger engines. The increase in cruise Mach number and hence block speed compensates for the aircraft weight increase in determining DOC.

In the area of noise reduction, there is an additional benefit associated with the use of oversized engines. Since the aircraft with oversized engines are not takeoff critical, a takeoff flap setting lower than that required for minimum field length may be selected. The lower flap angle will result in increased initial climb gradient and, for an EBF aircraft, a

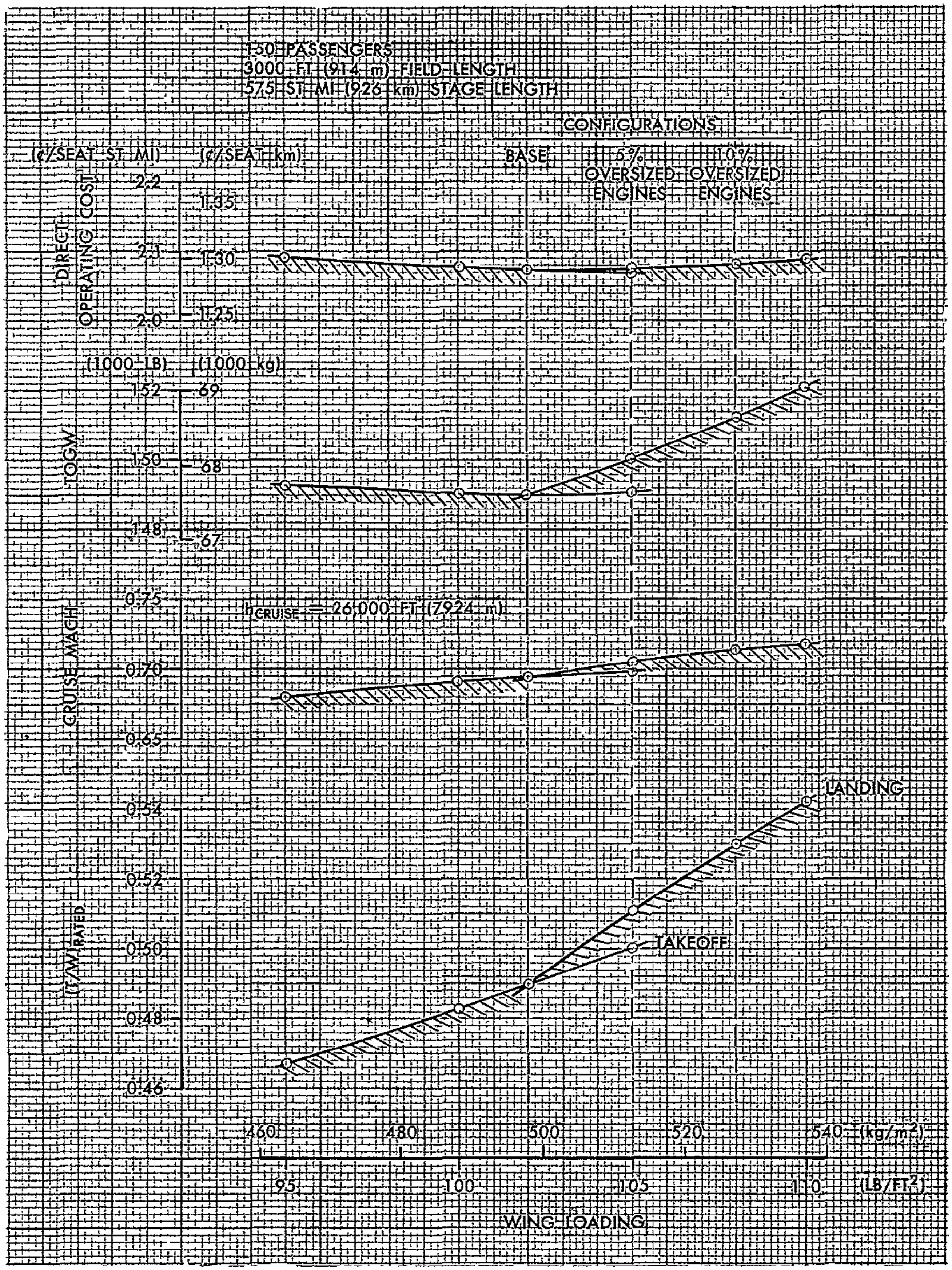


FIGURE 3-8. SIZING FOR EXTERNALLY BLOWN FLAP WITH OVERSIZED ENGINES

Table 3-6

EBF WITH OVERSIZED ENGINES

PD287-3 Engines (1.25 FPR)

		BASE AIRCRAFT	5% OVERSIZED	10% OVERSIZED
Payload	Passengers	150	150	150
Field Length	Ft (m)	3,000 (914)	3,000 (914)	3,000 (914)
Takeoff Gross Weight	Lb (kg)	149,000 (67,600)	150,100 (68,100)	151,200 (68,600)
Wing Area	Sq Ft (m^2)	1,461 (135.7)	1,430 (132.8)	1,400 (130.1)
Thrust Per Engine	Lb (N)	18,260 (81,220)	19,160 (85,230)	20,040 (89,140)
W/S	Lb/Sq Ft (kg/m^2)	102 (498)	105 (513)	108 (527)
T/W		0.490	0.510	0.530
OEW	Lb (kg)	102,610 (46,540)	103,290 (46,850)	103,900 (47,130)
Aspect Ratio		8.0	8.0	8.0
Mcr @ 26,000 Ft (7925 m)		0.69	0.71	0.71
Block Fuel @ 575 St Mi (926 km)	Lb (kg)	11,530 (5,230)	11,840 (5,370)	12,200 (5,530)
DOC @ 575 St Mi (926 km)	¢/ASSM (¢/ASKM)	2.075 (1.289)	2.077 (1.290)	2.082 (1.293)
EPNL at 500 Ft (152 m) Sideline	EPNdB	97.1	96.9	96.9

reduction in flap interaction noise. The reduction in flap interaction noise results in lower sideline noise levels than the base aircraft even though total thrust is larger. For the 10 percent oversized aircraft, the allowable

reduction in takeoff flap angle is just over 6 degrees (0.1 rad) which produces a decrease in sideline noise of 0.2 EPNdB. Figure 3-9 shows the effect of engine oversizing on noise impact based on a uniform population distribution. The reduction in noise impact is due primarily to the shorter takeoff noise contours which result from the increase in thrust-to-weight ratio. It appears that oversizing the engines by more than 10 percent for this specific configuration will not produce further noise reductions.

A penalty associated with the use of larger engines, other than higher aircraft weights and initial cost, is an increase in fuel consumption. A 10 percent increase in engine size is accompanied by a 6 percent increase in block fuel at the design range of 575 statute miles (926 m) as illustrated in Figure 3-10.

In summary, an increase in engine size for the E-150-3000 aircraft can be achieved without any significant DOC penalty although at the expense of increased fuel usage. The effect of engine oversizing on aircraft noise and community impact are further discussed in Section 5.4.4 and 5.6.5.

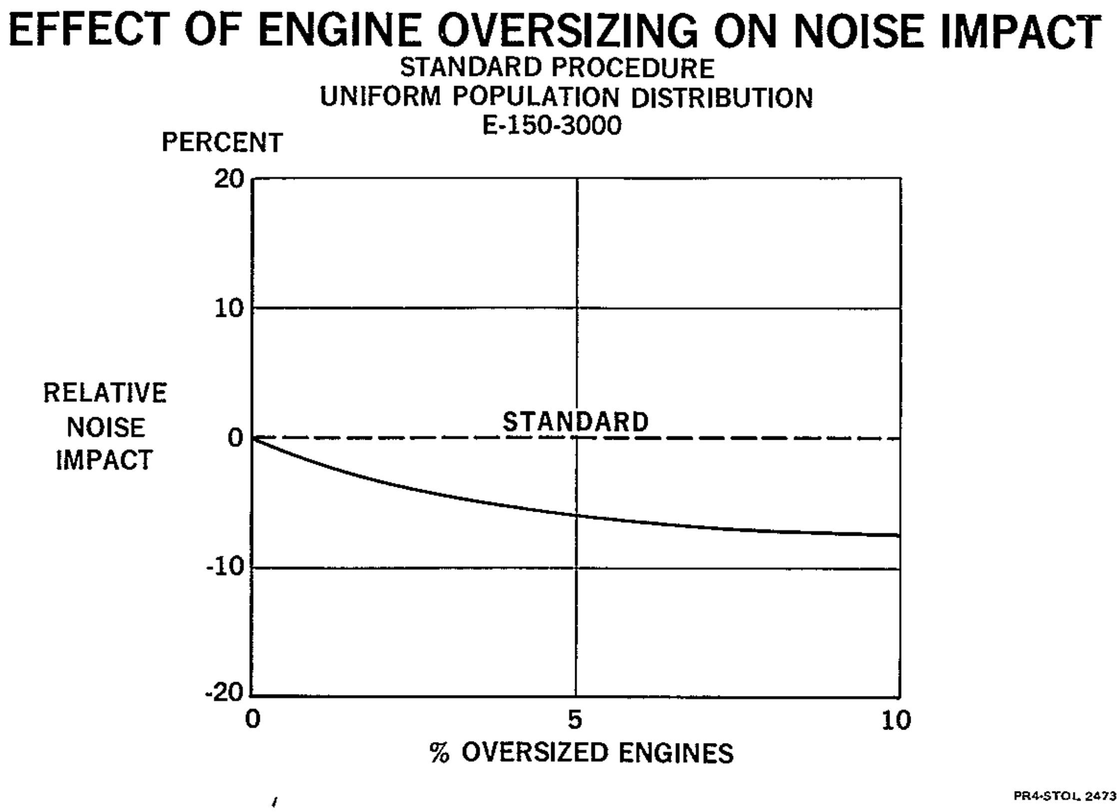


FIGURE 3-9. EFFECT OF ENGINE OVERSIZING ON NOISE IMPACT

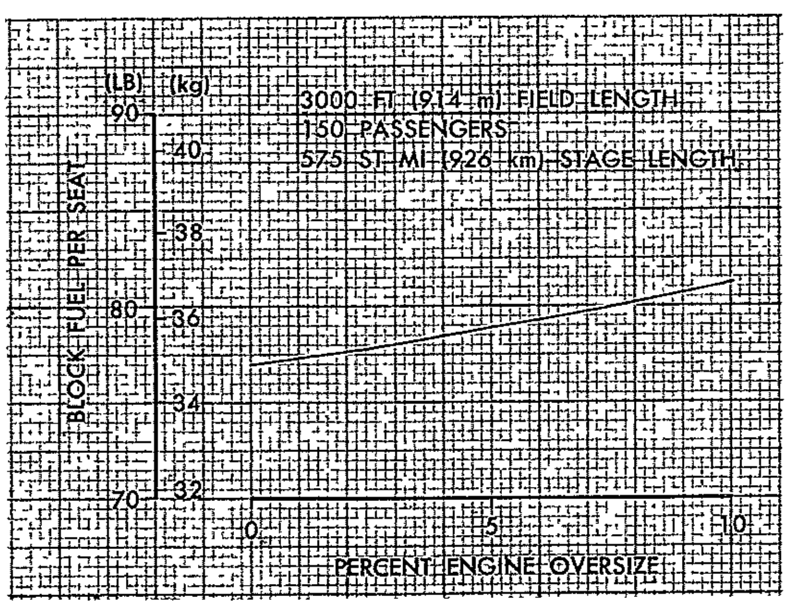


FIGURE 3-10. EFFECT ON FUEL CONSUMPTION OF OVERSIZING EXTERNALLY BLOWN FLAP AIRCRAFT ENGINES

4.0 PROPULSION SYSTEM & ACOUSTIC TRADE STUDY

4.1 Objectives

A trade study was conducted to determine the effect of engine cycle characteristics and degree of acoustic treatment on aircraft sizing, economics and noise level for 150-passenger, 3000-foot (914 m) and 4000-foot (1219 m) field length mechanical-flap aircraft.

4.2 Engine Definition and Performance

4.2.1 Engine Cycles - Three engine cycles were selected for the study. Fan pressure ratio was the primary independent variable since noise, thrust lapse, and cruise performance are strongly dependent on this parameter. Maximum turbine inlet temperatures were the same for all engines to maintain the same technology level, and component efficiencies were comparable to those of the QCSEE engines of Reference 1 for consistency in the two studies. (See Section 4.2.2.) Bypass ratio was established at a value which resulted in a primary jet exhaust velocity at takeoff sufficiently low that the primary jet is not the dominant noise source.

The fan pressure ratio range studied was 1.32 to 1.57. The value of 1.32 was selected because it was upper limit at which engine companies had previously indicated variable-pitch fans could be operated in the reverse-thrust mode. The ability to obtain reverse-thrust by use of reverse pitch has advantages in weight, cost, and maintenance over cascade or other nacelle-mounted thrust reversers. Engines with lower fan pressure ratios were not considered because they have less cruise thrust and larger diameters, which, particularly with a two-engine aircraft, can cause installation and ground

handling problems.

The highest takeoff fan pressure ratio engine used in the study was 1.57. This level is typical of current technology fans which have noise levels of the order of (FAR 36) - 10 dB. Also, an engine with this fan pressure ratio and near optimum bypass ratio of 5.9 was available and had been used in a similar trade study on an EBF aircraft in Reference 1. A 1.45 fan pressure ratio was selected for an intermediate value.

Variable-area fan nozzles were used with the 1.32 and 1.45 FPR engines to maximize available cruise thrust (Section 4.2.2.3).

Studies were conducted to determine bypass ratios for the 1.32 and 1.45 FPR engines. The Allison PD287-6 engine (Reference 3) has a FPR of 1.32 but a bypass ratio restrained by a requirement for a primary velocity of 700 ft/sec (213 m/sec). This cycle was designed for 95 PNdB noise level for a propulsive-lift installation, where noise is more sensitive to exhaust velocity than it is with an installation such as that on the MF aircraft, where the engine exhaust does not impinge on the flap. Using a lower bypass ratio with a higher primary exhaust velocity for the 1.32 FPR fan increases the cruise thrust and the specific thrust at takeoff, and makes the engine less sensitive to losses.

Figure 4-1 shows the increase in specific thrust and primary exhaust velocity at takeoff power as bypass ratio is decreased, for an engine with a fan pressure ratio of 1.32. The noise penalty associated with the primary velocity is shown in Figure 4-2 as a function of bypass ratio, with relative values of thrust and specific fuel consumption. Both the primary jet noise and the core noise are functions of the primary exhaust velocity in the

SPECIFIC THRUST AND PRIMARY VELOCITY AT TAKEOFF

FAN PRESSURE RATIO = 1.32

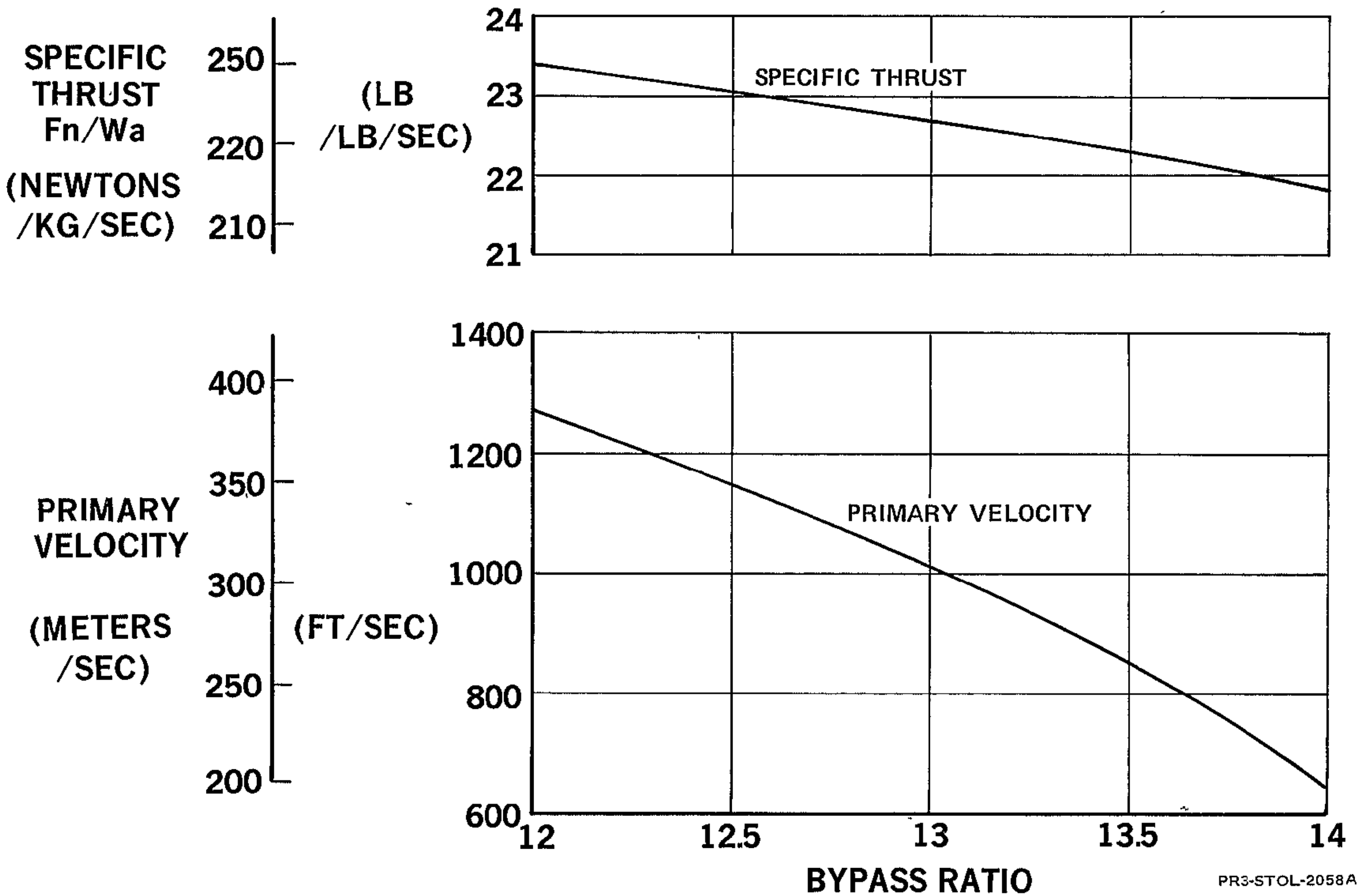


FIGURE 4-1

EFFECT OF BYPASS RATIO WITH 1.32 FPR FAN

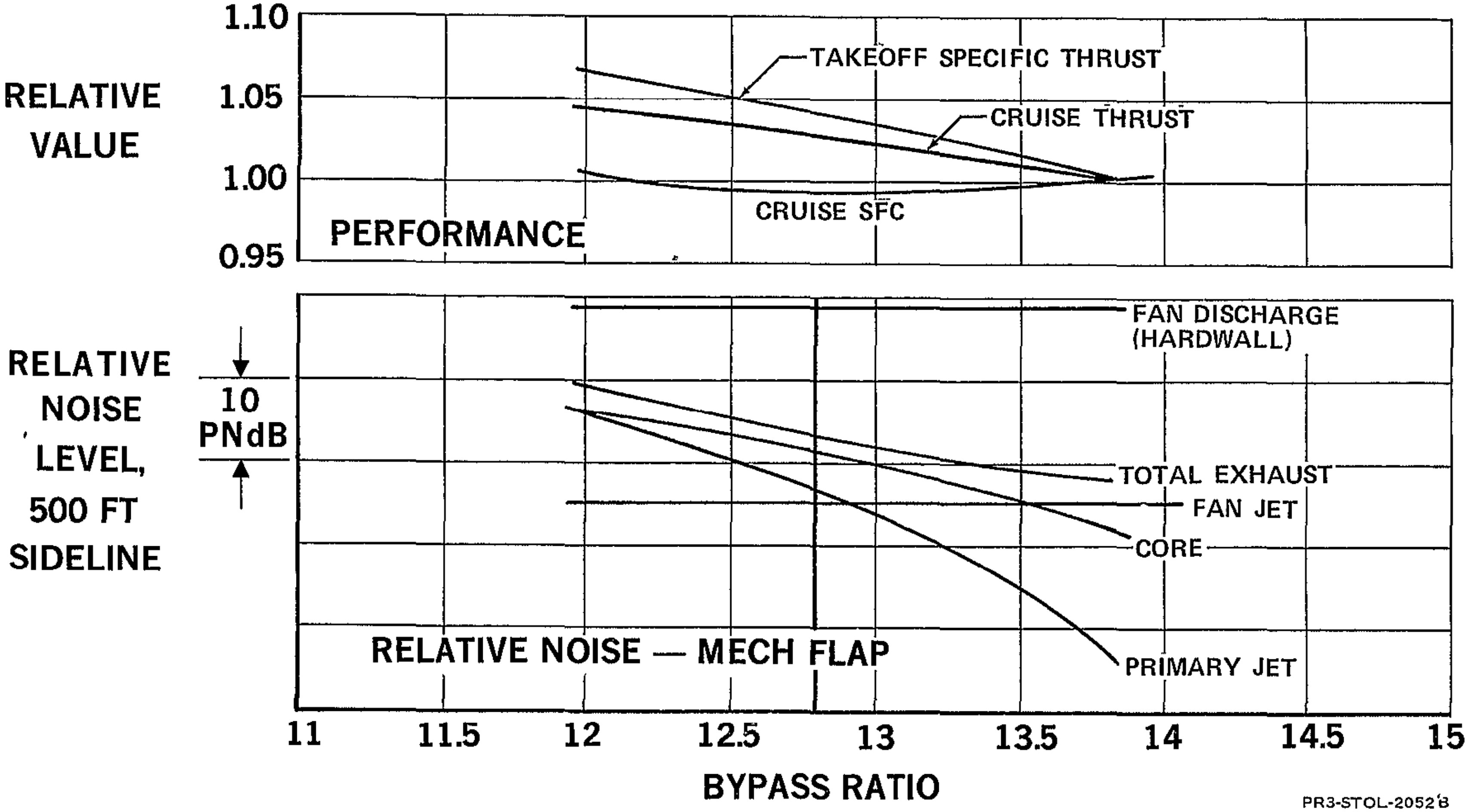


FIGURE 4-2.

noise estimation methods used in this study. (See Appendix C.1). The results shown in Figure 4-2 led to the selection of a value of 12.8 as a bypass ratio for the engine with a fan pressure ratio of 1.32. At this point the cruise SFC was at a minimum value. At lower bypass ratios, higher takeoff specific thrust (which results in better engine thrust/weight) and more cruise thrust are available, but the primary velocity increases to a range where the primary jet and core noise would be significant factors in the total noise level of an engine with acoustical treatment.

The gains in engine performance by going to a bypass ratio of 12.8 from the value of 13.8 are shown in Figures 4-3 and 4-4 and summarized in Table 4-1.

Table 4-1

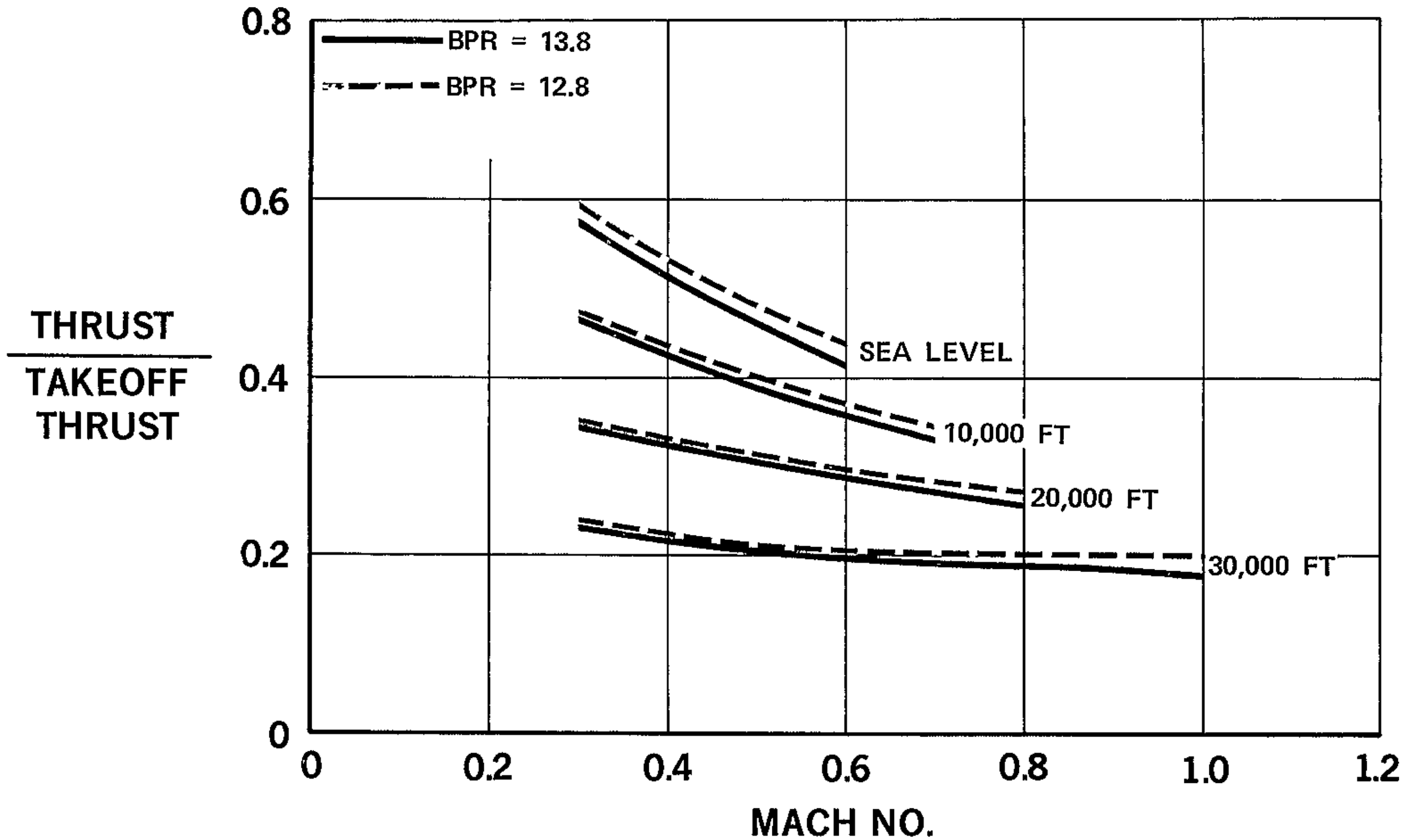
ENGINE PERFORMANCE CHANGE
12.8 BPR VS 13.8 BPR

	Change Due to Lower BPR
Fan Diameter	- 2.0%
Engine Thrust/Weight	+ 2.3%
Climb Thrust (20,000 ft; 0.6 M_0)	+ 3.0%
Max. Cruise Thrust (30,000 ft; 0.7 M_0)	+ 4.5%
Min. SFC @ Cruise	- 1.4%

A study of the effect of bypass ratio on an engine cycle having a fan pressure ratio of 1.45 was conducted in a similar manner. The results are shown in Figure 4-5. A bypass ratio of 9.2 was selected for the 1.45 FPR engine to be used in the acoustic trade study. Table 4-2 summarizes pertinent characteristics of the engines considered in the trade study.

EFFECT OF BYPASS RATIO ON MAX CLIMB THRUST

FAN PRESSURE RATIO = 1.32



PR3-STOL-2079

FIGURE 4-3.

CRUISE PERFORMANCE COMPARISON

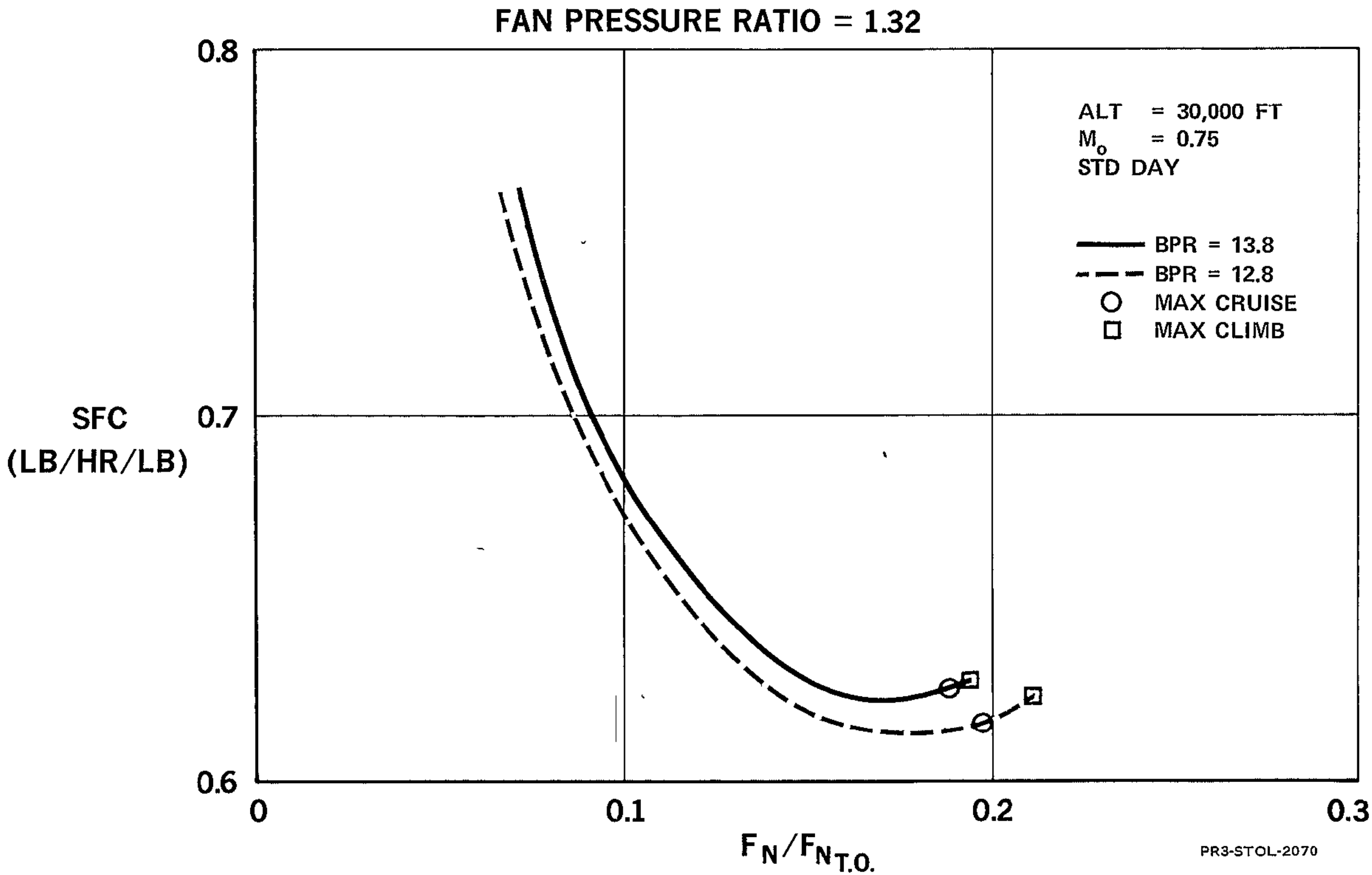


FIGURE 4-4.

EFFECT OF BYPASS RATIO WITH 1.45 FPR FAN

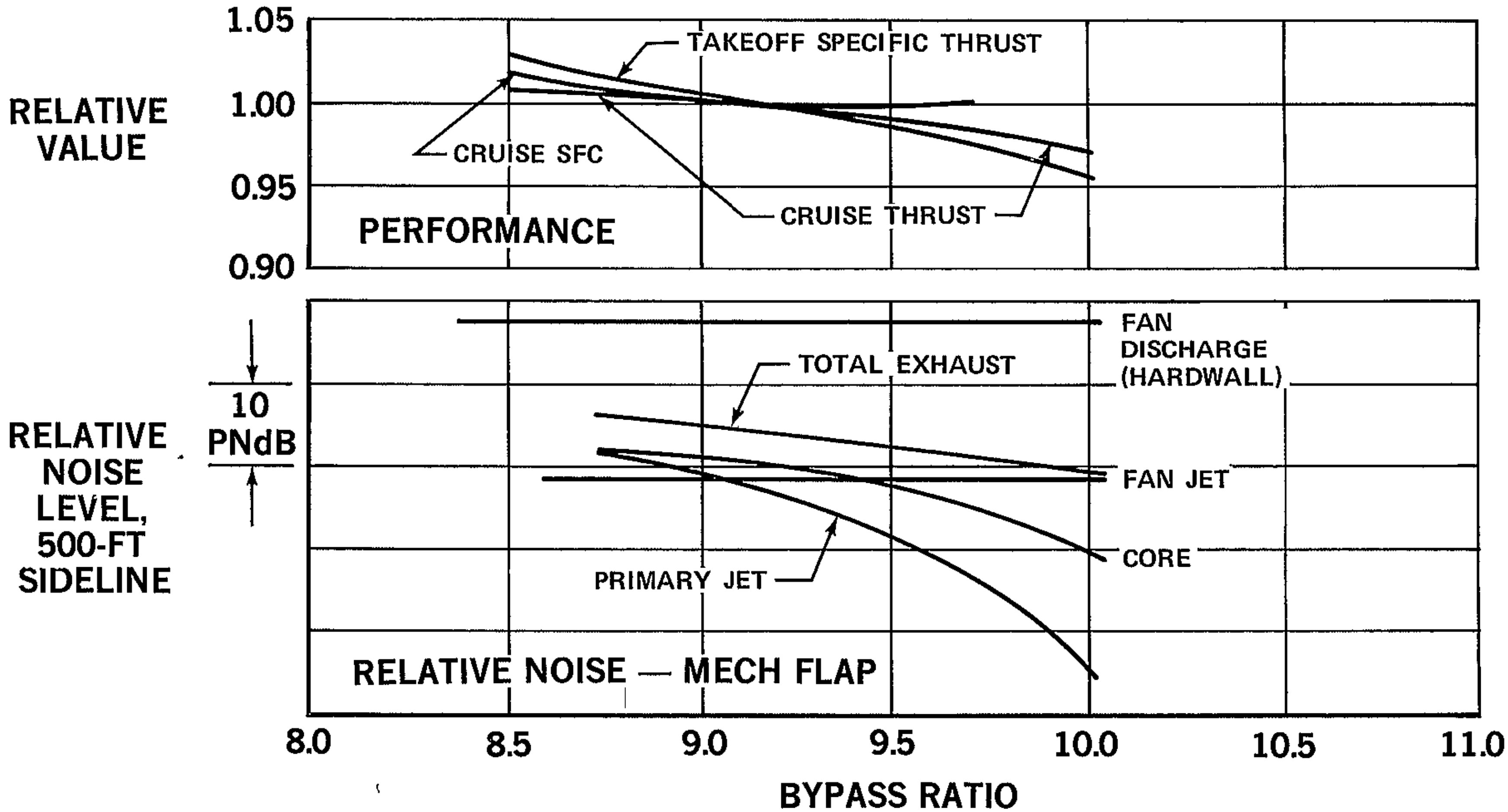


FIGURE 4-5.

Table 4-2

SUMMARY OF CHARACTERISTICS OF ENGINES

IN ACOUSTIC TRADE-STUDY

Designation	12.8/1.32	9.2/1.45	5.9/1.57
FPR	1.32	1.45	1.57
Bypass Ratio	12.8	9.2	5.9
Overall Pressure Ratio	20.0	21.8	22.7
Fan Tip Speed	925 ft/sec (282 m/sec)	1250 ft/sec (381 m/sec)	1550 ft/sec (472 m/sec)
Specific Thrust, F_n/w_{a_2}	22.9 (224 N/kg/sec)	26.5 (260 N/kg/sec)	30.4 (298 N/kg/sec)
Thrust Weight	6.69 lbs/lb	6.74 lbs/lb	6.92 lbs/lb
Above values at SLS, Std. Day			
$\frac{\text{Cruise Thrust}^*}{\text{Takeoff Thrust}}$	0.20	0.22	0.26
Cruise SFC*	0.59	0.61	0.60
Fan Configuration	Variable-Pitch	Fixed-Pitch	Fixed-Pitch
Nozzle Configuration	Variable-Area Fan Nozzle	Variable-Area Fan Nozzle	Fixed-Area Nozzles

* @ 30,000 ft., $M_o = 0.7$

The cycle performance for the above studies was generated using the component efficiencies and temperatures discussed in Section 4.2.2, with a thermodynamic cycle analysis program (SPEC) which calculates both design-point and off-design performance (Reference 4).

4.2.2 Component Technology Levels - The technology level of the engine cycles used in this study was consistent with the engines used in the Reference 1 study. Component efficiencies and maximum temperatures used in estimating engine performance were values which resulted in duplication of the performance of the Allison PD287-6 reference engine (Reference 3).

4.2.2.1 Fan Performance - The performance map for the 1.32 pressure ratio variable-pitch fan is shown in Figure 4-6. This map is for the design blade angle. The design point fan efficiency, η_{fan}, is 0.90. The fan performance for the 1.45 FPR engine was generalized from Figure 4-6, using an efficiency of 0.88 at the design point. Figure 4-7 shows design point fan efficiency as a function of design point pressure ratio, for various existing and proposed fans, including the study engines.

4.2.2.2 Other Engine Components - High pressure compressor, combustor, and turbine parameters are listed in Table 4-3. Also shown are the turbine inlet temperatures used to define the operating levels for takeoff, maximum climb, and maximum cruise thrust settings.

4.2.2.3 Nozzle Performance - The fan and primary nozzle characteristics were from Reference 3. The velocity coefficients are shown in Figures 4-8 and 4-9, and the nozzle discharge coefficients in Figures 4-10 and 4-11. The fan nozzle area schedule for the 1.32 FPR engine, Figure 4-12, is that of the PD287-6. Figure 4-12 also shows the operating curve assumed for the 1.45 FPR

VARIABLE PITCH FAN MAP

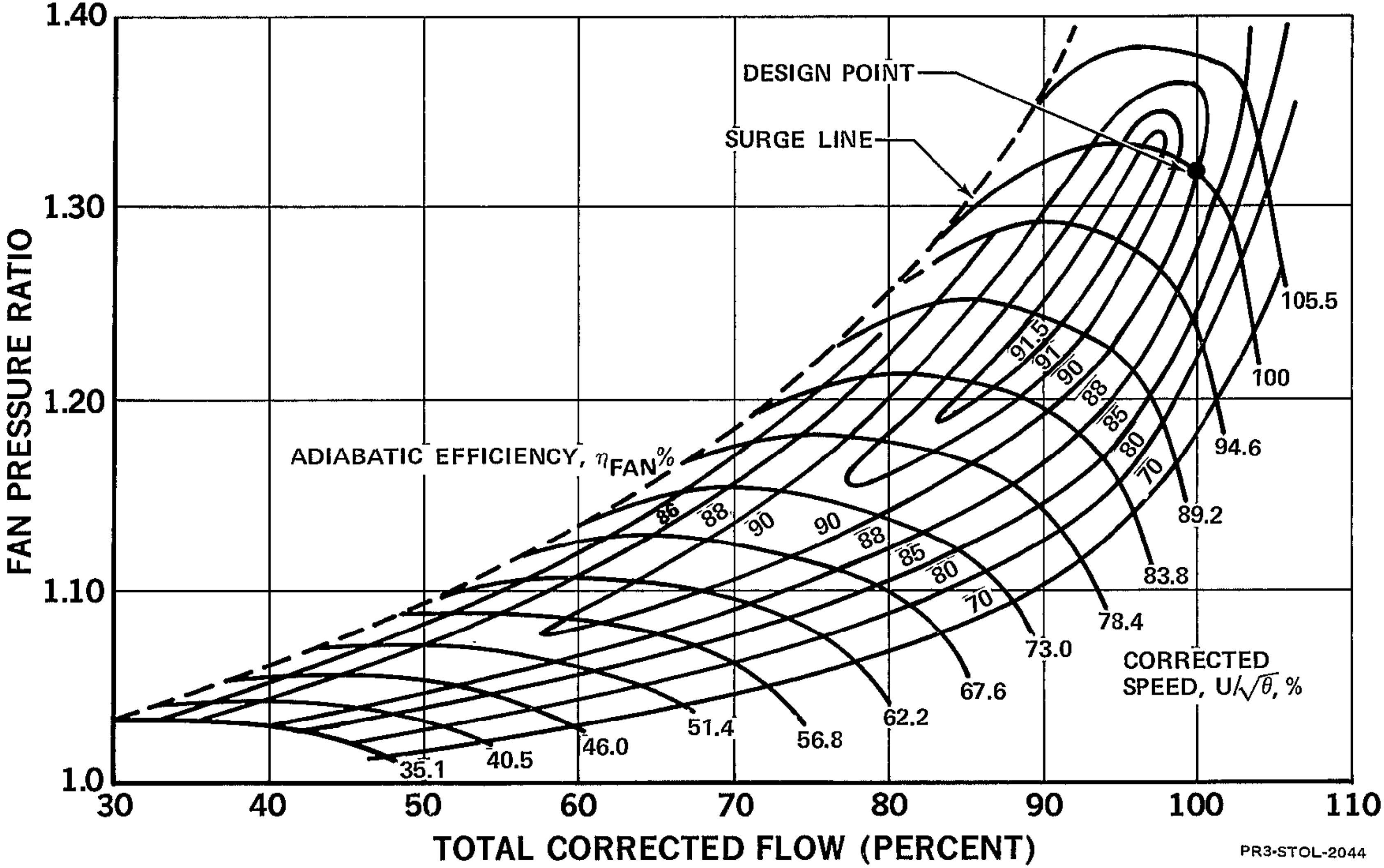


FIGURE 4-6.

FAN EFFICIENCY AT TAKEOFF PRESSURE RATIO

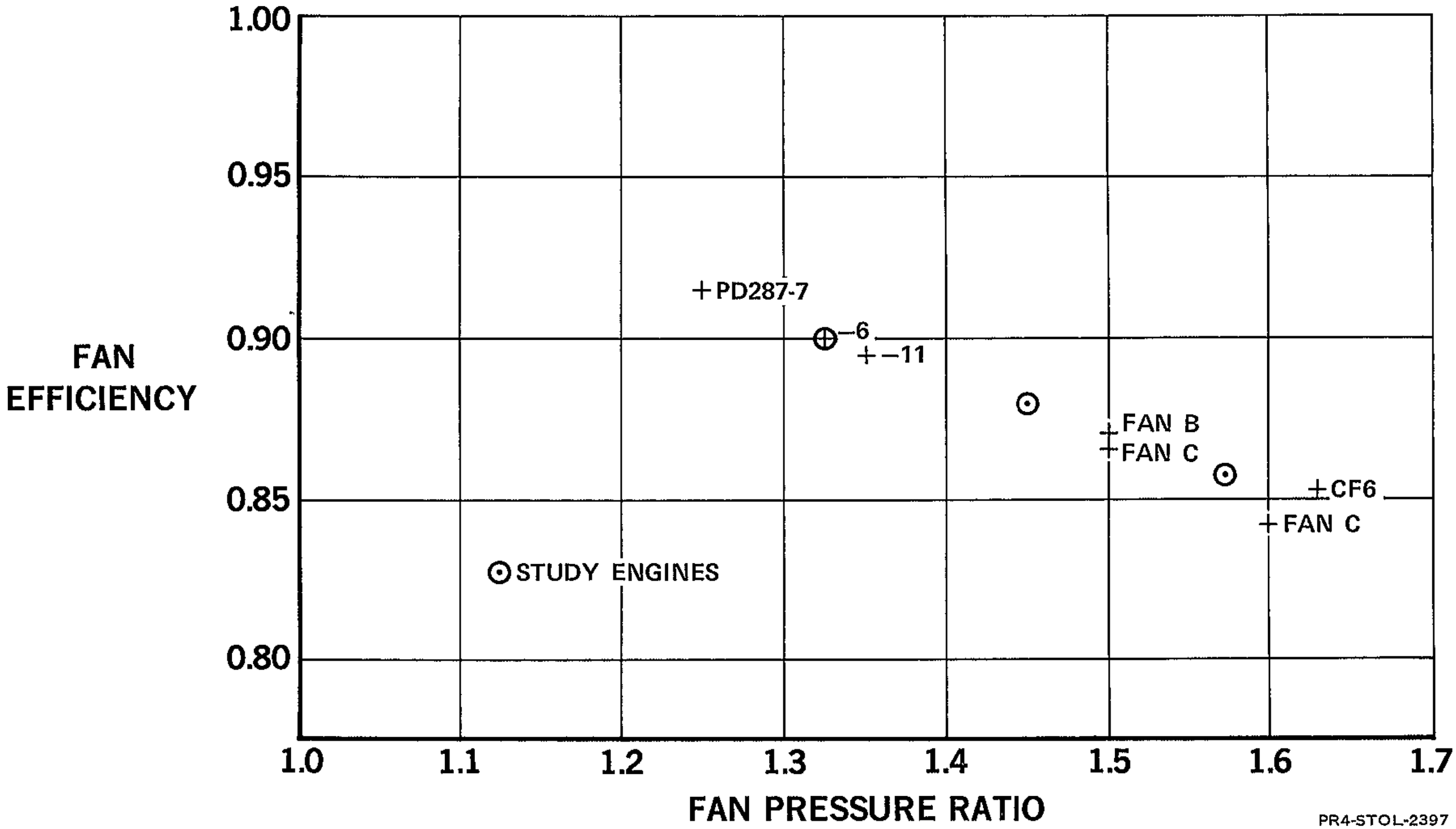


FIGURE 4-7.

engine. The effect of fan nozzle area on cruise performance was investigated for a 1.45 FPR engine with the result shown in Figure 4-13. The degree of variation with Mach number illustrated in Figure 4-12 was made consistent with that of the 1.32 FPR engine, with the level of the Mach .75 value set at that for maximum thrust from Figure 4-13.

Table 4-3

DESIGN POINT COMPONENT EFFICIENCIES

	Percentage
H.P. Compressor Efficiency	83.6
Combustion Efficiency	99.5
Burner Pressure Loss	5
H.P. Turbine Efficiency	89.5
L.P. Turbine Efficiency	90.5

Turbine Inlet (Burner Out) Temperatures:

Takeoff, 90°F (33°C) : 2960°R (1644°K) (max)

Takeoff, Std. Day : 2805°R (1558°K)

Max. Climb : 2695°R (1497°K)

Max. Cruise : 2600°R (1444°K)

FAN NOZZLE VELOCITY COEFFICIENT

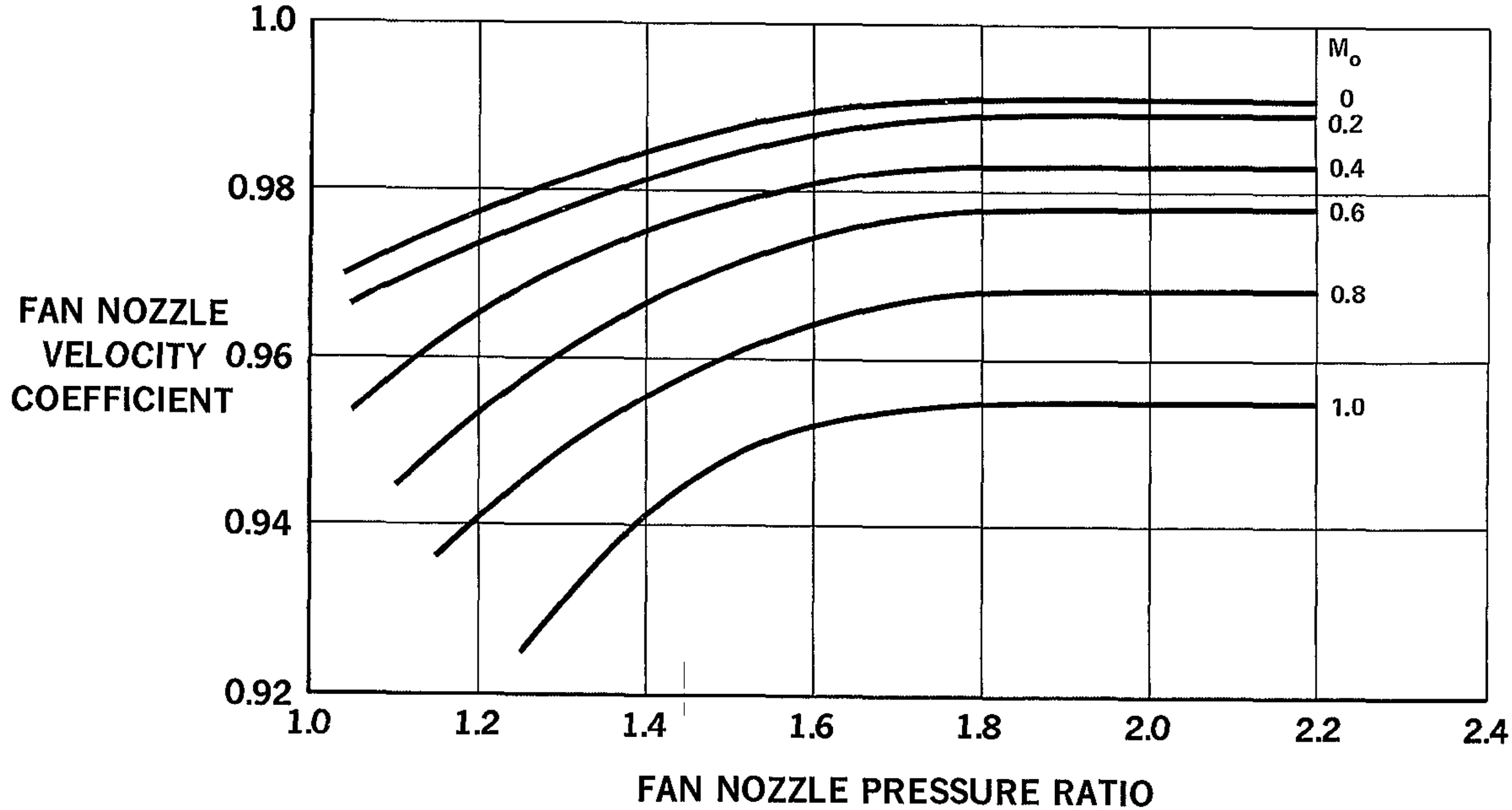


FIGURE 4-8.

PR3-STOL-2077

PRIMARY NOZZLE VELOCITY COEFFICIENT

$M_0 = 0 - 1.0$

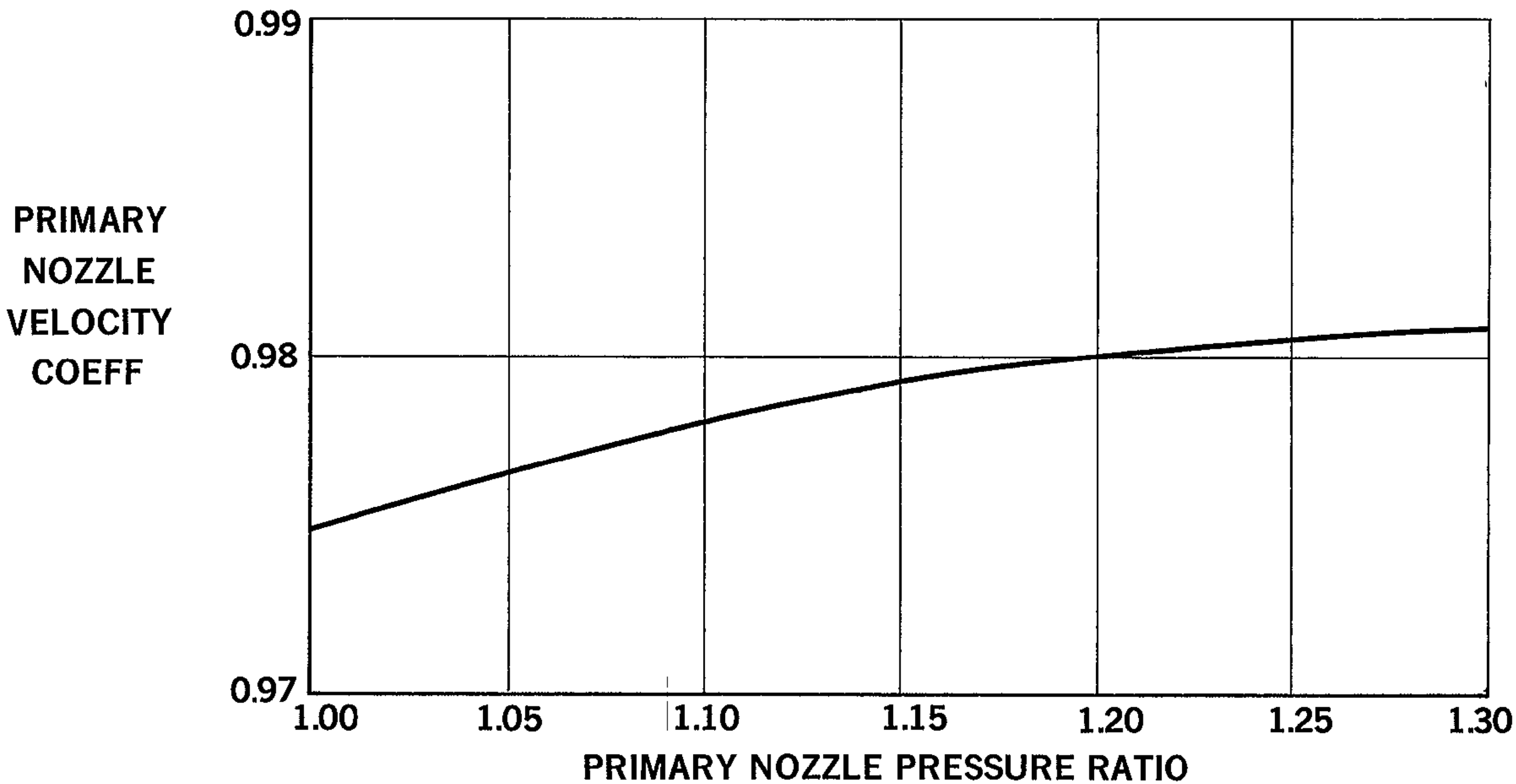
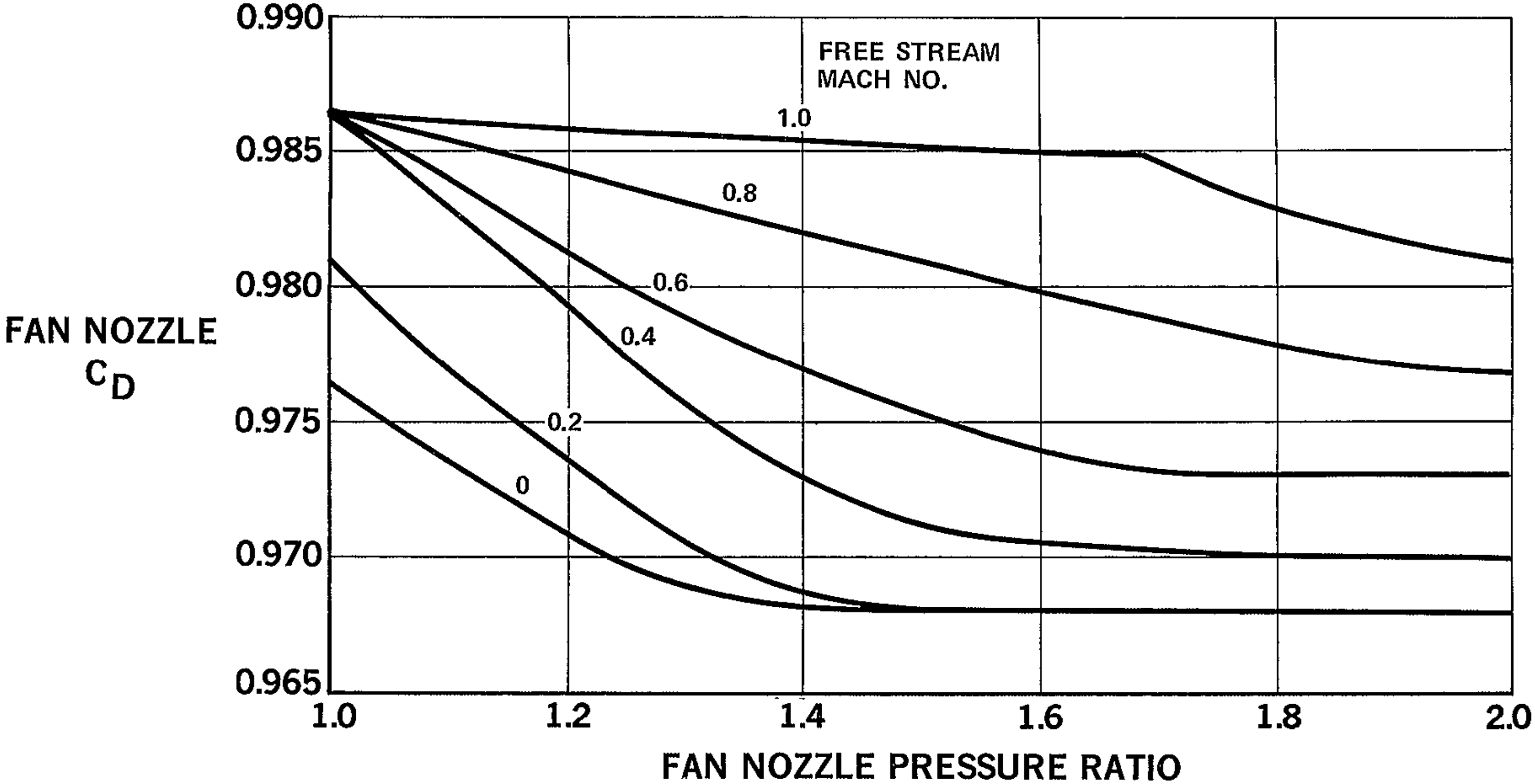


FIGURE 4-9.

PR3-STOL-2066

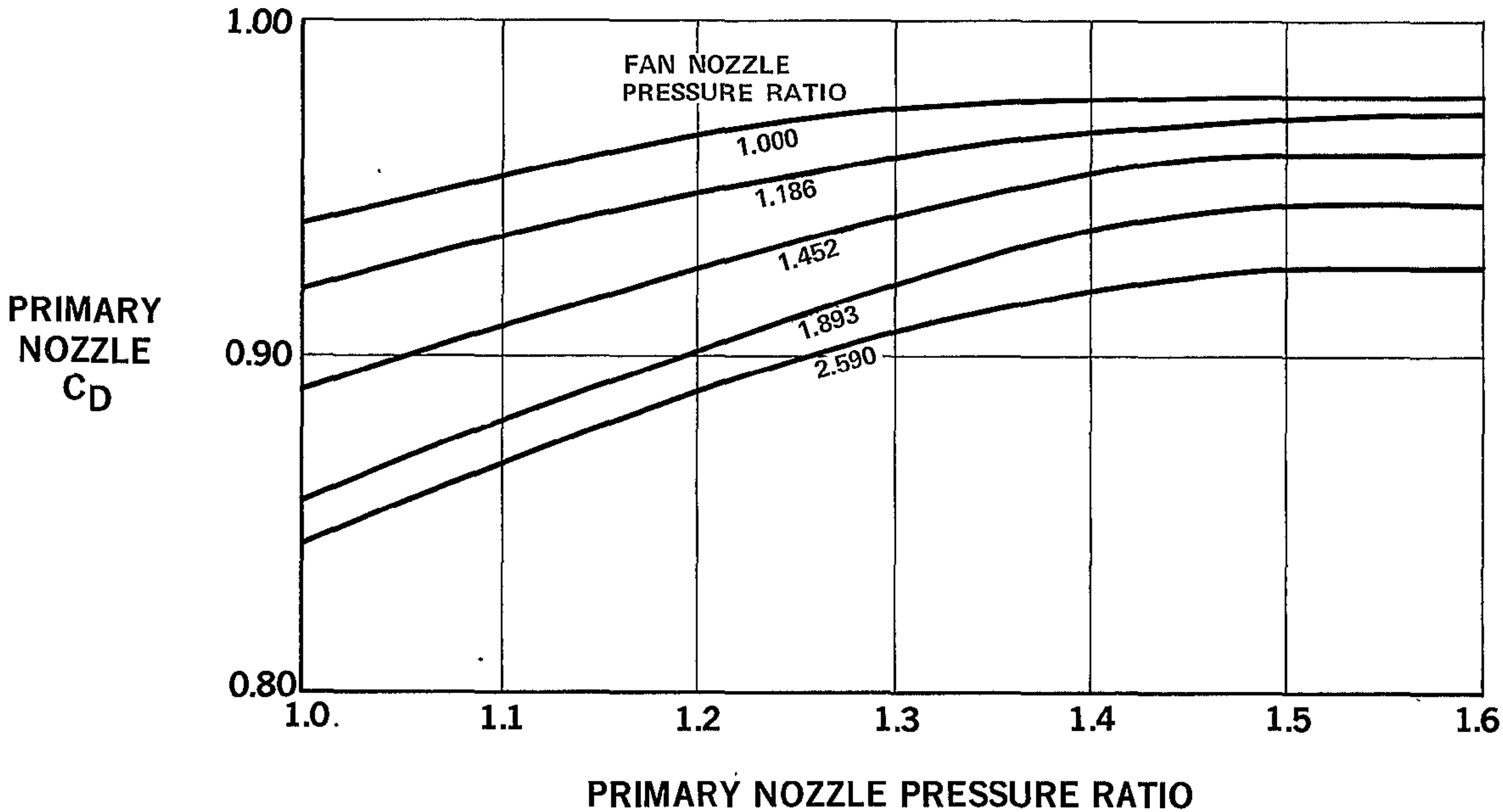
FAN NOZZLE DISCHARGE COEFFICIENT



PR3-STOL-2063

FIGURE 4-10.

PRIMARY NOZZLE DISCHARGE COEFFICIENT



PR3-STOL-2064

FIGURE 4-11.

FAN EXHAUST NOZZLE AREA VARIATION

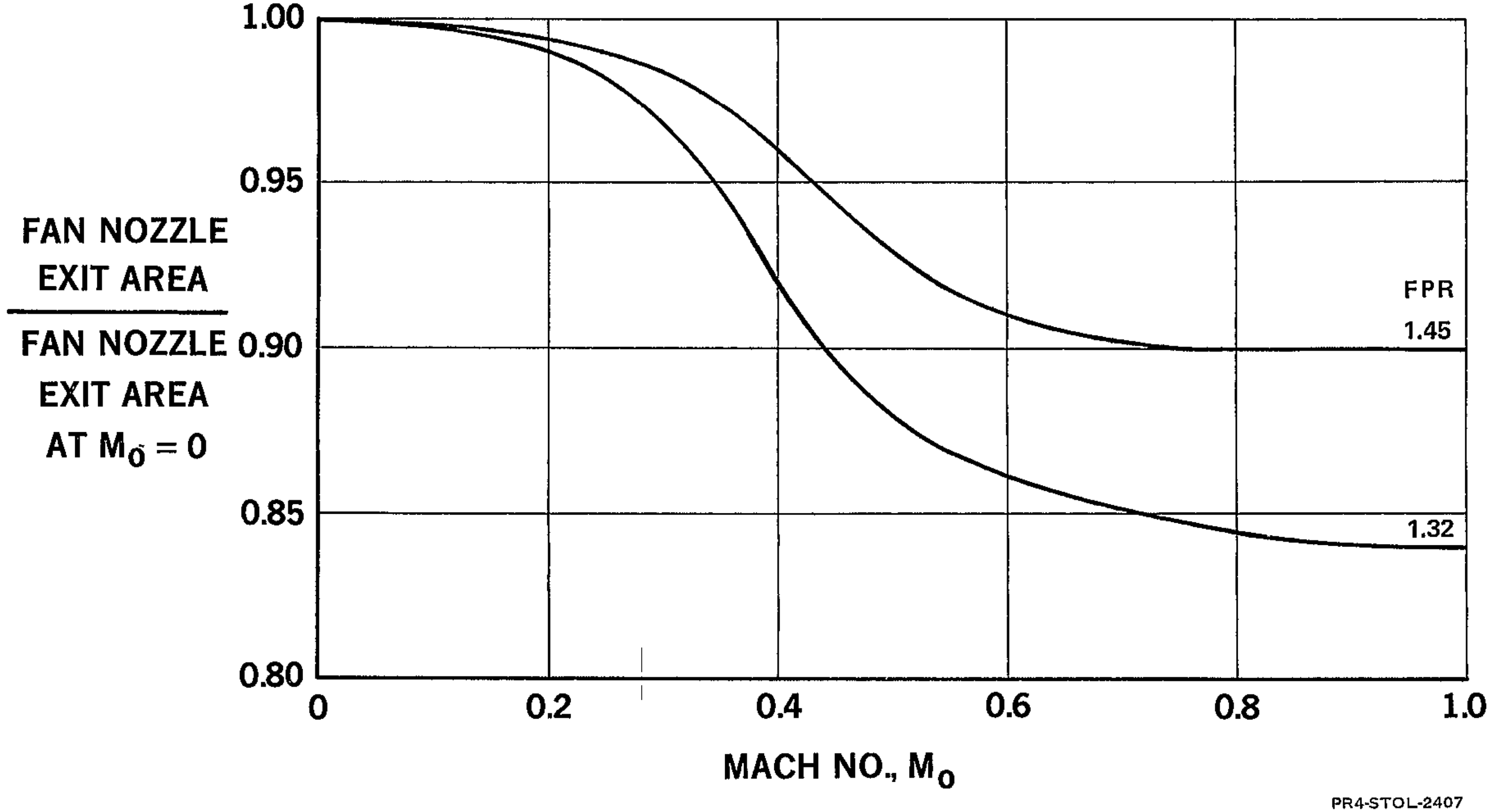
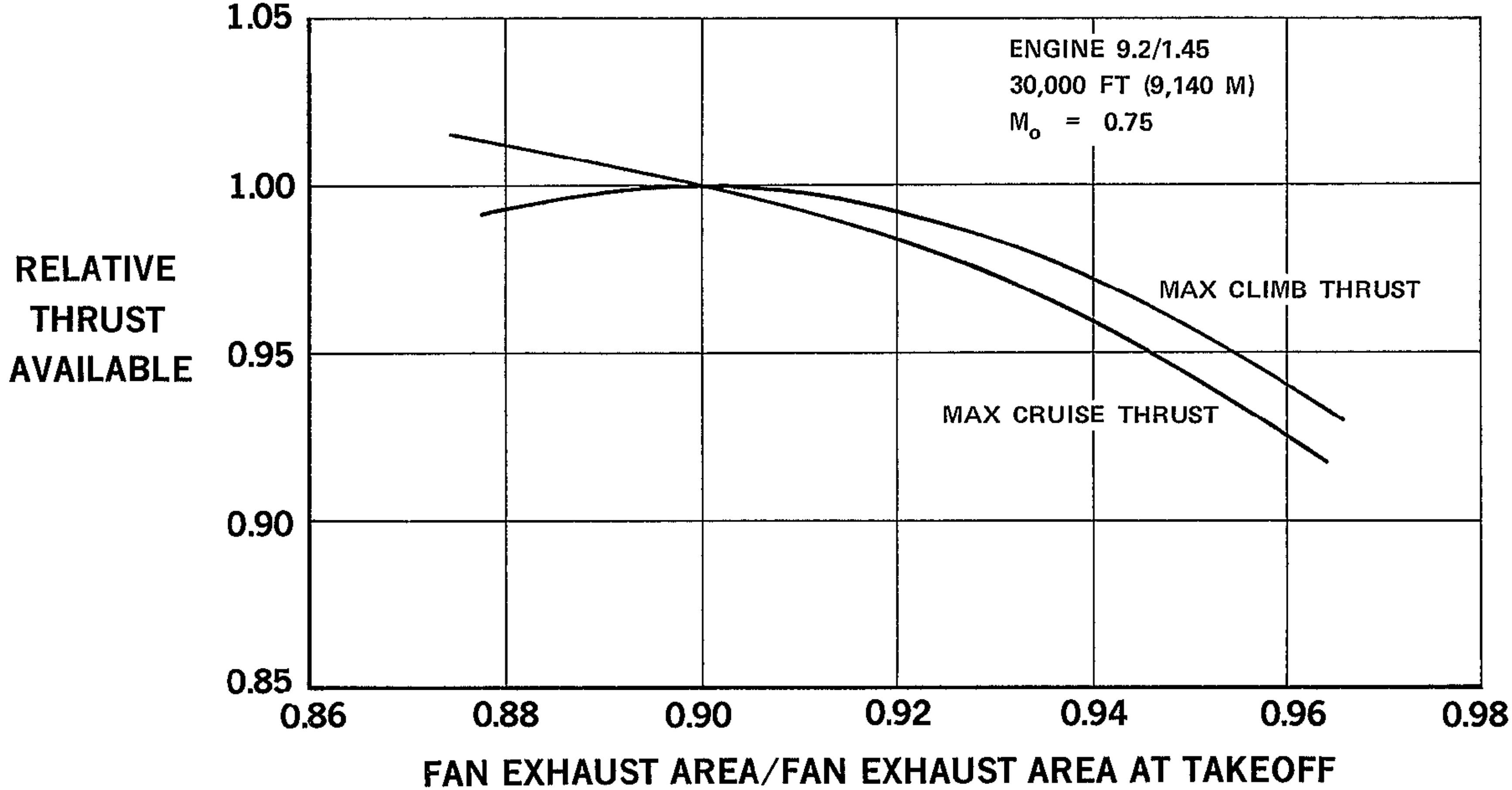


FIGURE 4-12.

EFFECT OF FAN NOZZLE AREA AT CRUISE



PR4-STOL-2406

FIGURE 4-13.

4.2.3 Engine Weights and Dimensions - The engine weights were estimated assuming the same technology level previously used in Reference 1 . The results for the three engines are shown in Table 4-4 .

For the EBF airplane, the engine weight was that used for the EBF airplane in Reference 1 .

4.2.3.1 Component Weights - Engine component weights were compiled from References 6 through 8 , and parameterized. Fan blade containment is presently required for commercial engines and is expected to be required for these study aircraft. Weight for fan blade containment was estimated for each engine, based on the method described in Section 4.2.3.2. Figures 4-14 through 4-18 show the weight correlations used for the fan, high pressure compressor, combustor, high and low-pressure turbines, and engine systems.

Fan weight was estimated as a function of fan pressure ratio and inlet airflow as shown in Figure 4-14. The high pressure compressor weight correlation used is on Figure 4-15 as a function of compression ratio for a fixed value of the core air flow corrected to the conditions at the compressor exit. For other airflows, the weight from the figure was scaled by the airflow ratio to the 1.16 power, or

$$\text{H.P. Compressor Weights} = (\text{Ref. Weight})\left(\frac{W_{a_{HP}}\sqrt{\theta_{HP}}}{\delta_{HP}}\;\frac{1}{\text{Ref. Airflow}}\right)^{1.16}$$

Figure 4-15 gives combustor weights as a function of the same corrected airflow, the core flow corrected to the compressor outlet or combustor inlet conditions. The high pressure turbine weight in Figure 4-16

TABLE 4-4

ENGINE WEIGHT SUMMARY

Engine	12.8/1.32		9.2/1.45		5.9/1.57	
Thrust	35,000 lbs (155,700 N)		35,000 lbs (155,700 N)		30,000 lbs (133,400 N)	
	lbs	(kg)	lbs	(kg)	lbs	(kg)
Fan Wt.	2,095	(950)	1,920	(871)	1,630	(739)
HP Compr	525	(238)	525	(238)	575	(261)
Combustor	160	(73)	160	(73)	165	(75)
HP Turb	400	(181)	400	(181)	435	(197)
LP Turb	820	(372)	1,025	(465)	950	(431)
Gearing	480	(218)	395	(179)	0	(0)
Fan Blade Cont.	179	(81)	144	(65)	108	(49)
Other	570	(259)	625	(284)	475	(215)
Total	5,229	(2372)	5,194	(2356)	4,338	(1968)
Thrust/Weight	6.69		6.74		6.92	

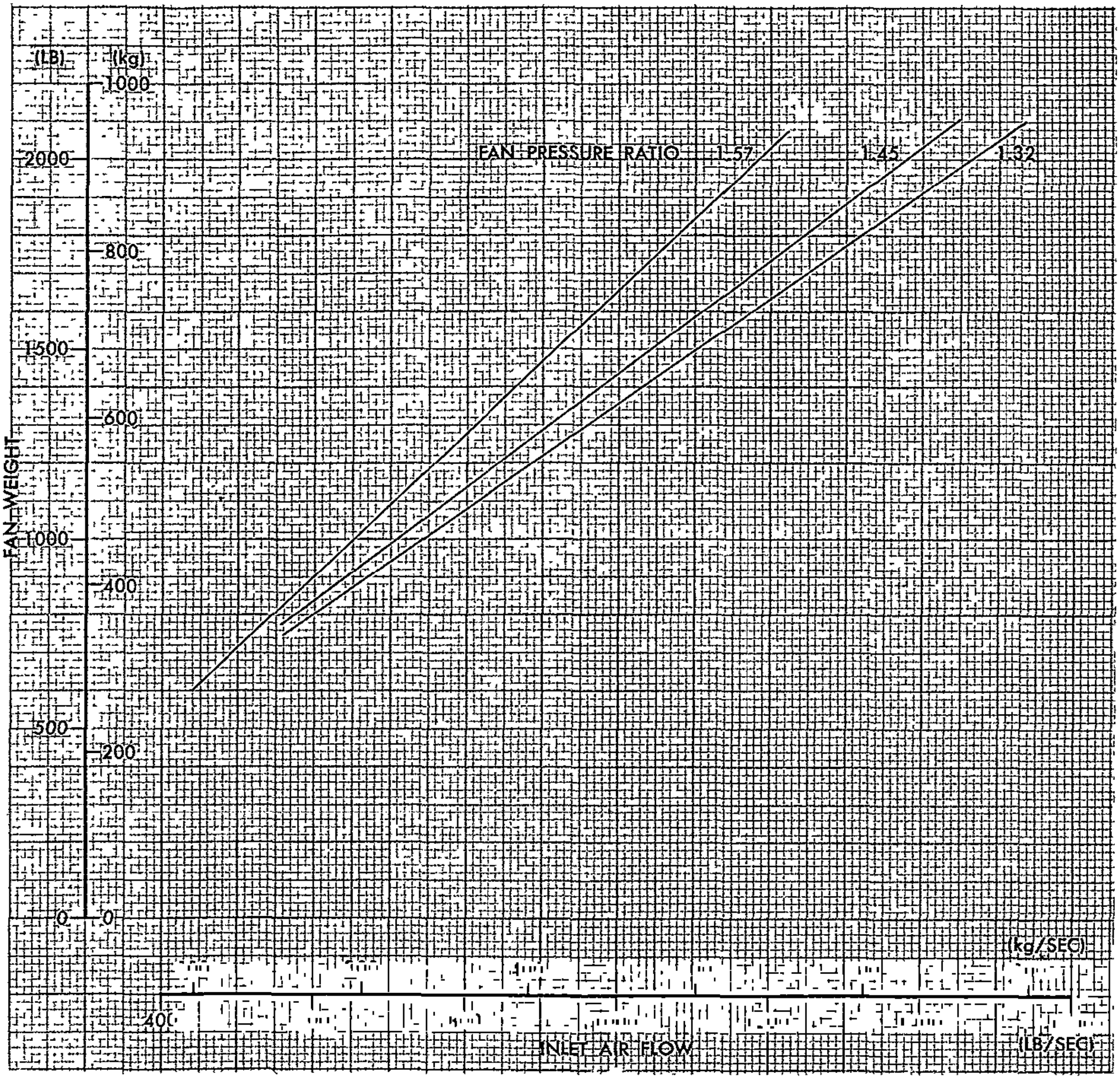


FIGURE 4-14. ENGINE COMPONENT WEIGHTS—FAN ESTIMATE

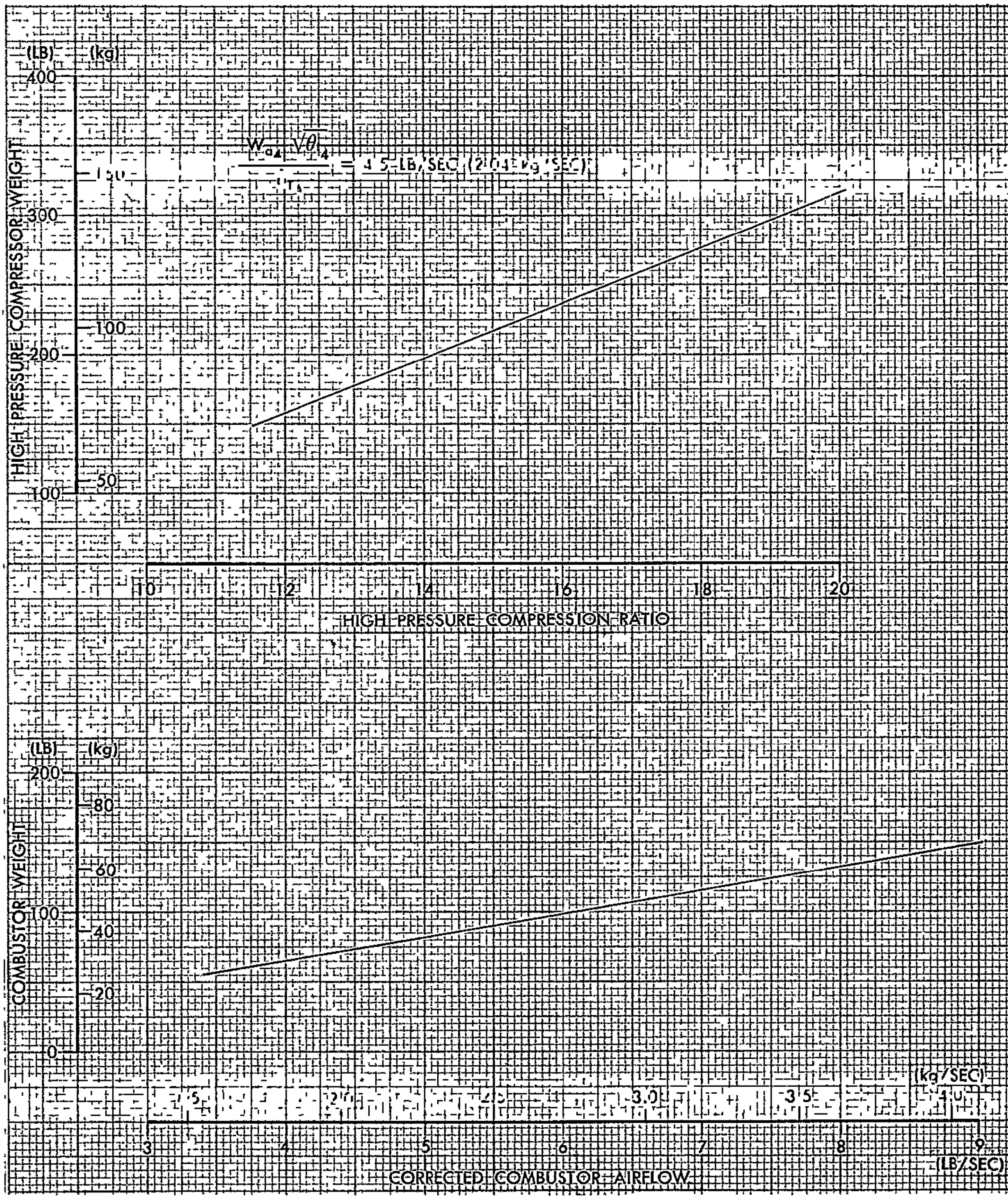


FIGURE 4-15. ENGINE COMPONENT WEIGHTS—HIGH PRESSURE COMPRESSOR ESTIMATE

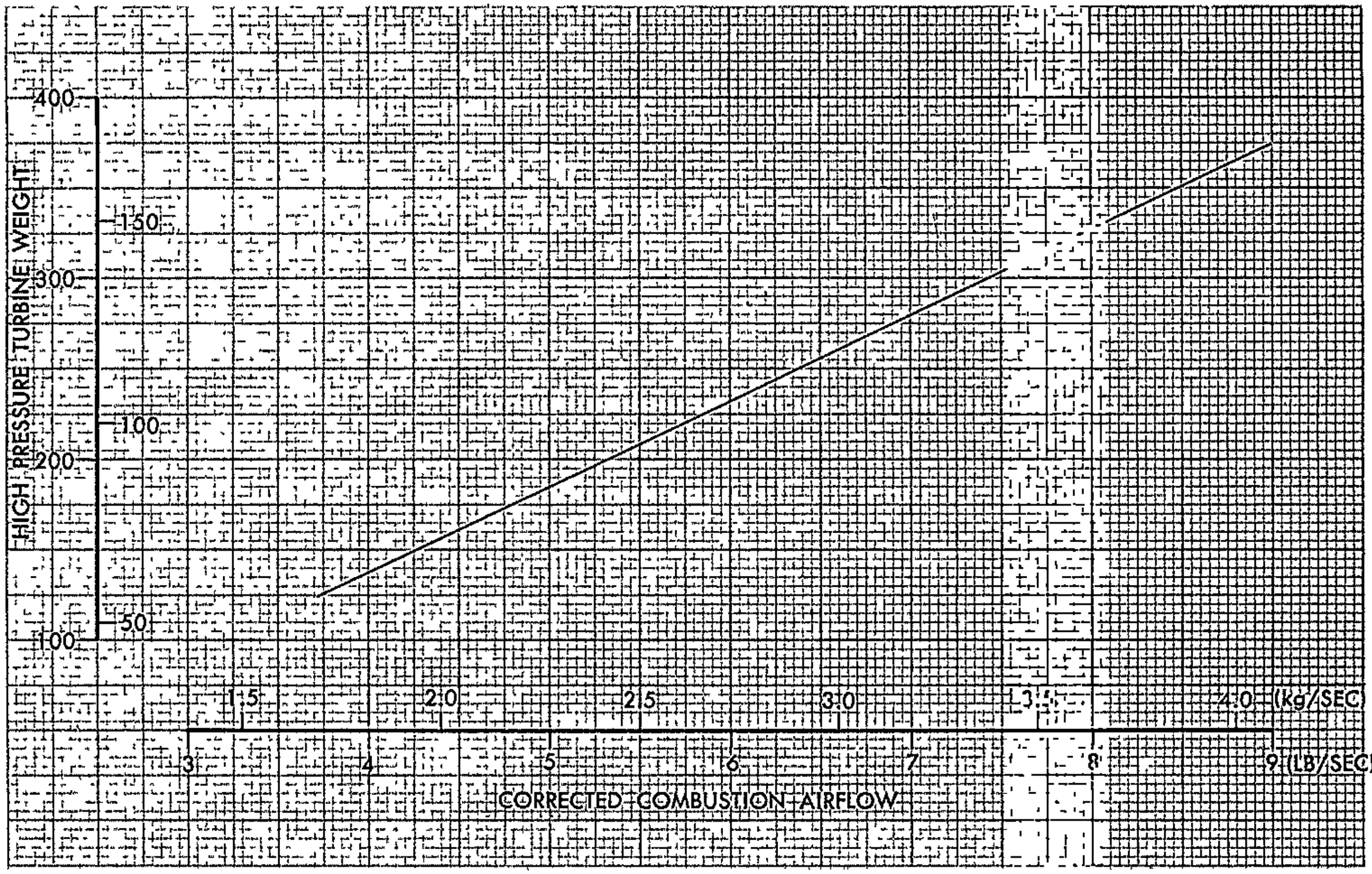


FIGURE 4-16. ENGINE COMPONENT WEIGHTS—HIGH PRESSURE TURBINE ESTIMATE

was correlated as a function of the same parameter. Low pressure turbine weight in Figure 4-17 varies as the low pressure turbine power. Engine systems weights (lubrication system, engine fuel pump, controls, etc.) are shown in Figure 4-18 as a function of the low pressure turbine power, as this parameter gave the best correlation. Values are shown for engines with geared and with direct-drive fans.

For engines with geared fans, the gear weight was estimated to be:

$$\text{Gear Wt.} = 0.048\ (Q)^{0.84}$$

where the weight is in pounds and the torque, Q, in pound-feet based on the fan RPM. This is equivalent to

$$\text{Gear Wt.} = 0.01686(Q)^{0.84}$$

where weight is in kilograms and the torque, Q, is in newton-meters.

For comparison, the weights of the engines with a fan pressure ratio of 1.57 and 1.32 used in the acoustic trade study of Reference 1 were calculated by the above method. The results are given in Table 4-5 and show agreements within a few percent.

4.2.3.2 Fan-blade Containment - A study was conducted to estimate the fan-blade containment requirements for the three engines of the acoustic trade study.

A correlation was established between the fan blade kinetic energy and the effective thickness of the structure required to contain a single blade failure. The available data were plotted, Figure 4-19 , and an equation formulated to define the boundary between the contained and the

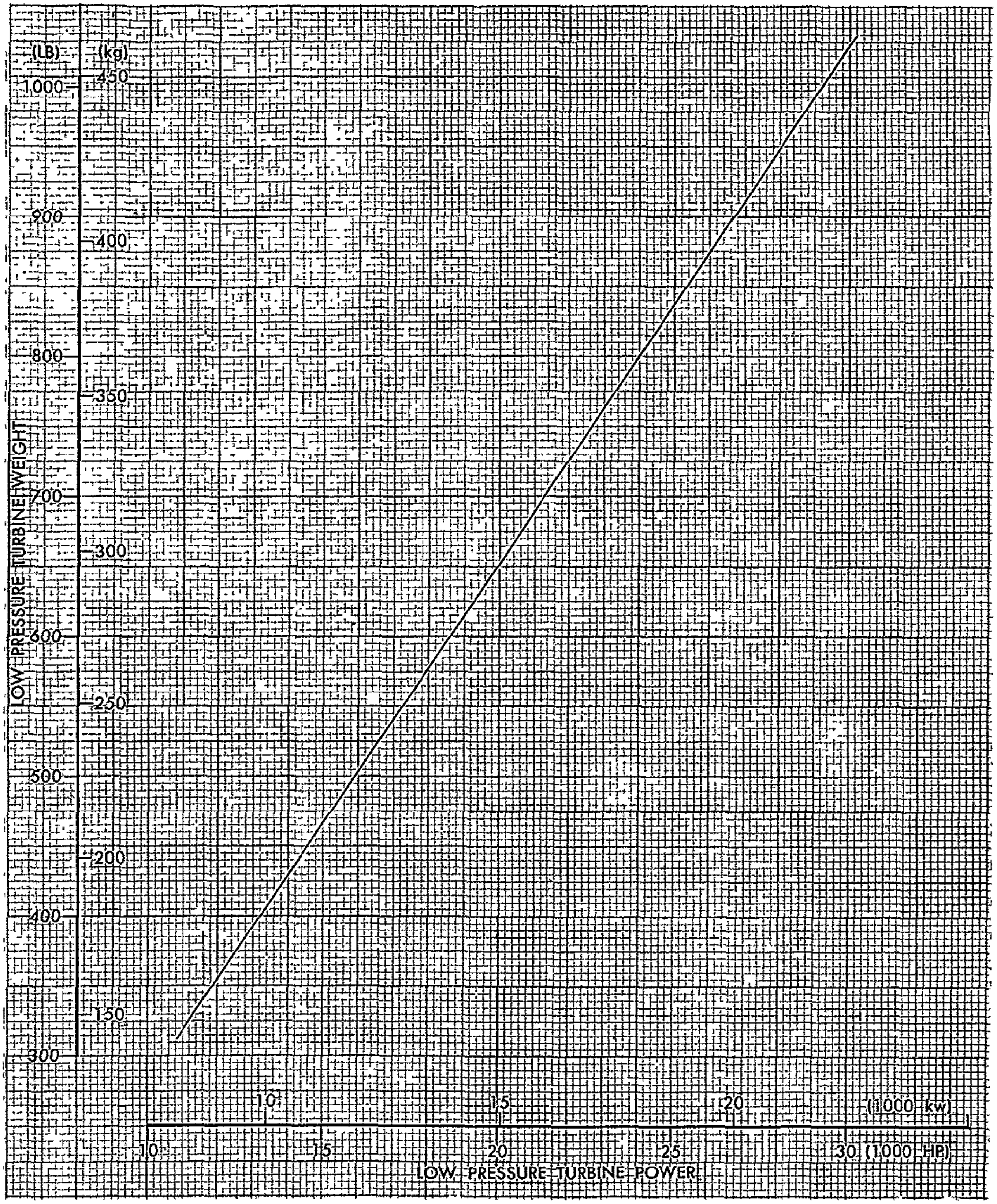


FIGURE 4-17. ENGINE COMPONENT WEIGHTS—LOW PRESSURE TURBINE ESTIMATE

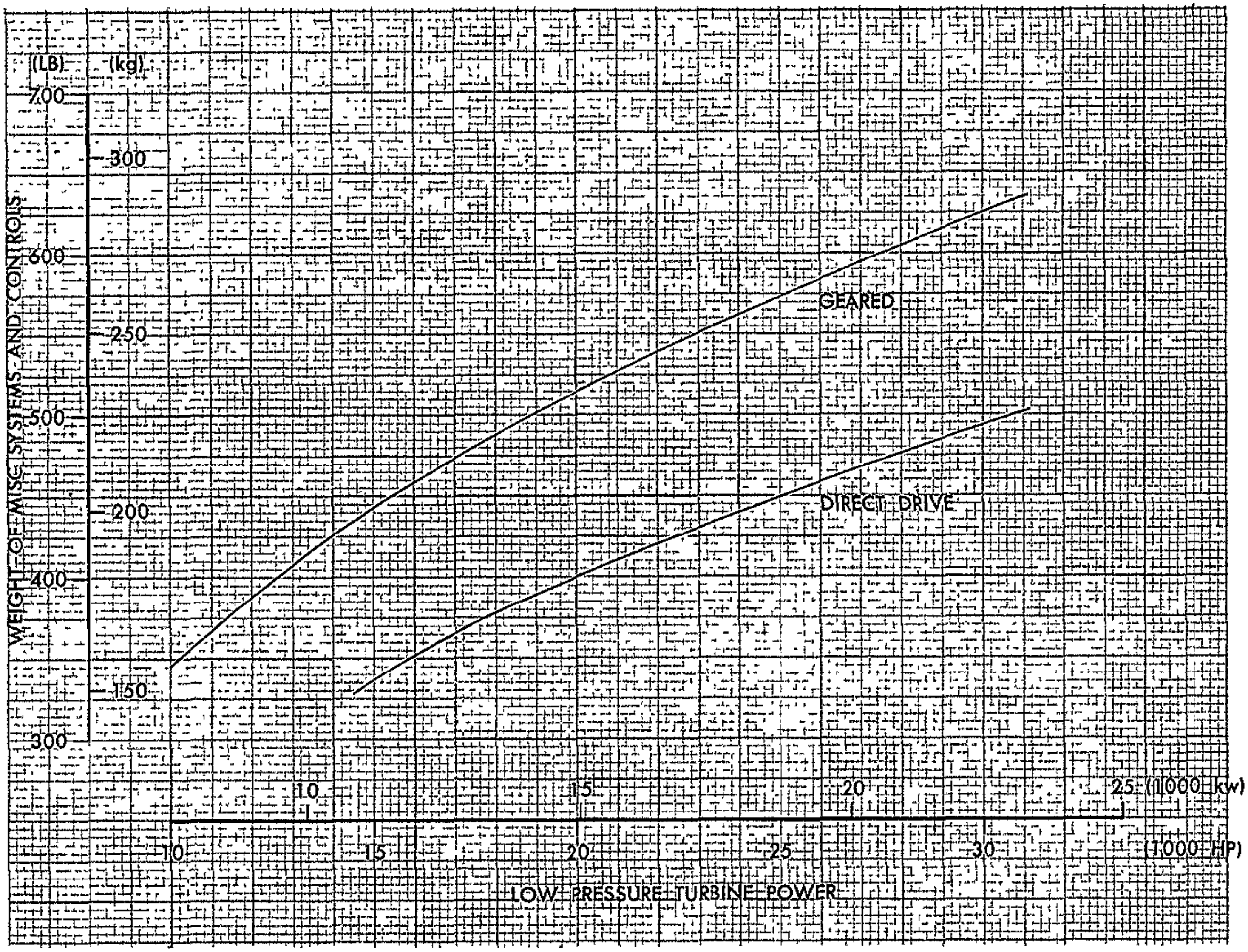


FIGURE 4-18. ENGINE COMPONENT WEIGHTS—ESTIMATE FOR MISC. SYSTEMS AND CONTROLS

Table 4-5

COMPARISON OF ESTIMATED WEIGHTS WITH

ENGINE WEIGHTS FROM REFERENCE 1

Fan Pressure	1.57		1.32	
Bypass Ratio	5.9		13.8	
Thrust	16,000 lb (71,200 N)		16,000 lb (71,200 N)	
Weights:	Lbs	Kg	Lbs	Kg
Fan	760	(345)	990	(449)
H. P. Compressor	280	(127)	205	(93)
Combustor	93	(42)	70	(32)
H. P. Turbine	213	(97)	152	(69)
L. P. Turbine	460	(210)	360	(163)
Gearing	0	(0)	188	(85)
Other	335	(152)	380	(172)
Total	2,140	(972)	2,345	(1,064)
Weight from Ref. 1	2,115	(960)	2,359	(1,070)

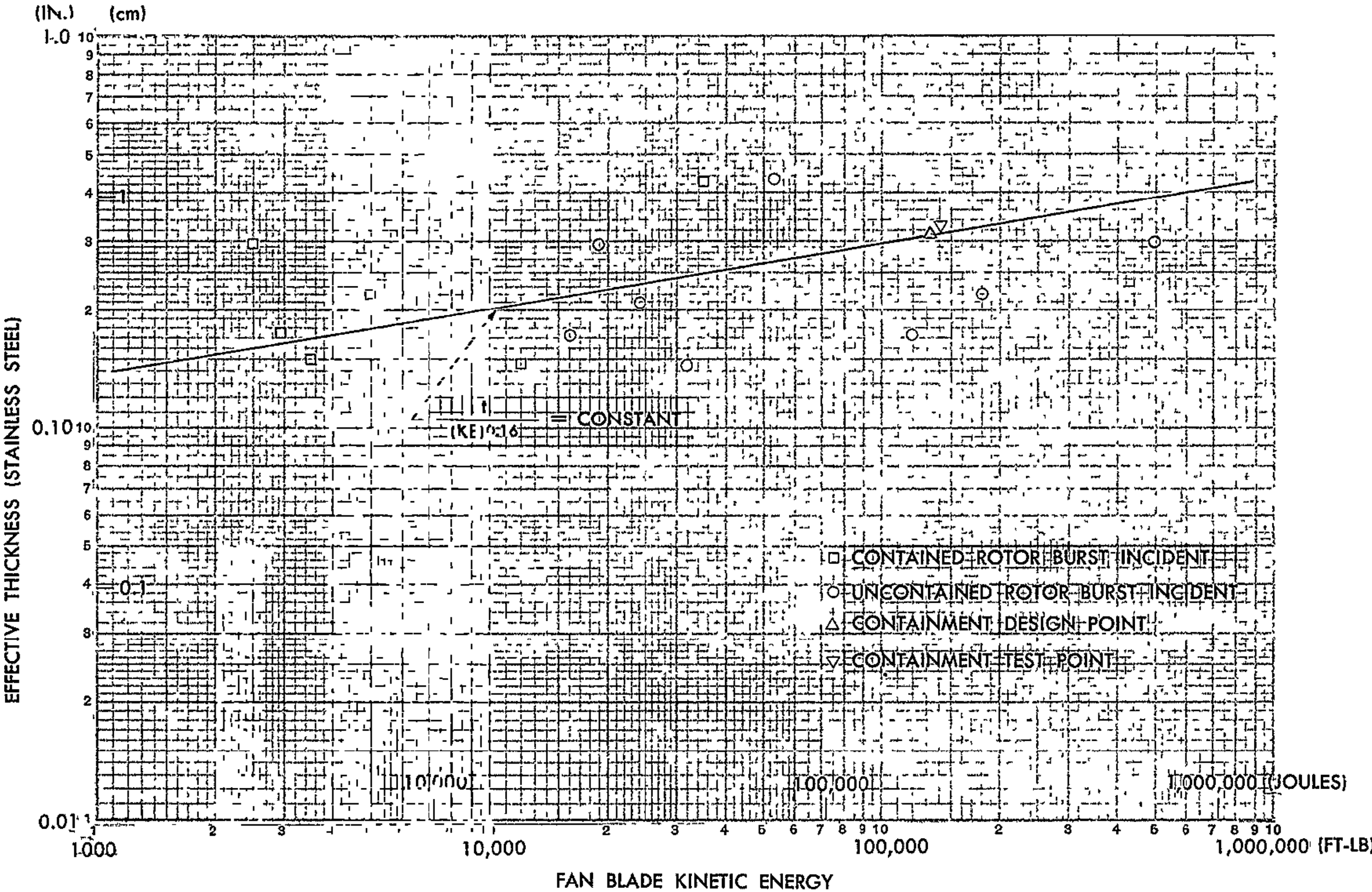


FIGURE 4-19. CONTAINMENT THICKNESS CORRELATION

uncontained points. The equation is:

$$\frac{t}{(KE)^{0.16}} = 0.0466$$

where t is the effective thickness of stainless steel in inches and KE is the fan-blade kinetic energy in foot-pounds, or,

$$\frac{t}{(KE)^{0.16}} = 0.1127$$

where t is in centimeters and KE is in joules.

For each engine, an estimate was made of the fan-blade kinetic energy. For the 1.32 and 1.45 fan pressure ratio engines, spar-shell construction of the fan blade was assumed. The fan blade weights were based on Allison and Hamilton Standard estimates of the weight exclusive of the spar, plus Douglas estimates of the spar weight. (Because of the low exponent on the kinetic energy term, containing the spar does not add appreciably to the containment penalty. For example, for a 20,000 pound (89,000 N) 1.32 fan pressure ratio engine, containing the spar adds 12 pounds (5.5 kg) to the engine weight over the weight which contains only the fan blade without the spar.) The effective thickness of stainless steel for containment was calculated using the above equation. The actual thickness of the fan case designs used to obtain the engine weights was estimated. The containment ring length was assumed to extend a distance equal to half the blade width plus 0.26 times the blade length, with a minimum value of the blade width plus 1-1/2 inches (3.8 cm). Table 4-6 shows the containment calculations.

4.2.3.3 Engine Dimensions - Overall engine dimensions for the installation drawings were determined by using the general dimension relationships of the

Table 4-6

FAN BLADE CONTAINMENT PENALTY SUMMARY

ENGINE	THRUST	FAN BLADE TANGENTIAL VELOCITY AT BLADE C.G.	FAN BLADE KINETIC ENERGY LEVEL	REQ'D. CASE EFF. THICKNESS FOR CONTAINM'T (STAIN. STEEL)	FWD. FAN CASE SECTION WEIGHT W/O CONTAINMENT	FWD. FAN CASE SECTION WEIGHT WITH CONTAINMENT	FAN BLADE CONTAINMENT WEIGHT PENALTY
	Lbs (Newtons)	ft/sec (m/sec)	ft-lbs (joules)	in (cm)	lbs (kg)	lbs (kg)	lbs (kg)
12.8/1.32/20	20,000 (89,000)	595 (181)	17,370 (23,550)	.222 (.564)	40 (18.1)	137 (62.1)	97 (44.0)
12.8/1.32/35	35,000 (156,000)	595 (181)	30,895 (41,890)	.244 (.620)	72 (32.7)	251 (113.9)	179 (81.2)
9.2/1.45/20	20,000 (89,000)	807 (246)	22,650 (30,710)	.232 (.589)	32 (14.5)	106 (48.1)	74 (33.6)
9.2/1.45/35	35,000 (156,000)	807 (246)	39,840 (54,020)	.254 (.645)	55 (24.9)	199 (90.2)	144 (65.3)
5.9/1.57/20	20,000 (89,000)	1127 (344)	42,400 (57,490)	.256 (.650)	40 (18.1)	112 (50.8)	72 (32.7)
5.9/1.57/30	30,000 (133,000)	1127 (344)	51,870 (70,330)	.265 (.673)	57 (25.8)	165 (74.8)	108 (49.0)

QCSEE Task I and II engines and other study engines of the same technology level.

The fan frontal area, A_f, was based on the SLS takeoff airflow W_{a_o}:

$$A_f = \frac{W_{a_o}}{32} \quad \text{where } A_f \text{ is in ft}^2$$

$$\text{and } W_{a_o} \text{ is in lbs/sec}$$

or

$$A_f = 64\, W_{a_o} \quad \text{where } A_f \text{ is in cm}^2$$

$$\text{and } W_{a_o} \text{ is in kg/sec}$$

The fan tip diameter, D_f, is:

$$D_f = \sqrt{\frac{4\, A_f}{\pi}}$$

The maximum diameter (including flanges) of each engine was assumed to be 3-1/2 inches greater than the fixed-pitch fan diameter and 6 inches greater for the variable-pitch fan.

The fan case length for the fixed-pitch fan was calculated from the relationship

$$L_{\text{fan case}} = 3.1 \ (W_{a_o})^{0.33}$$

where L is in inches and W_{a_o} is in lbs/sec, or

$$L_{\text{fan case}} = 10.22\, (W_{a_o})^{0.33}$$

if L is in cm. and W_{a_o} is in kg/sec.

For the variable-pitch fan, the case length was given by

$$\frac{L}{D_f} = 0.58$$

The engine length beyond the fan case was expressed as a function of the corrected core flow. For a non-geared engine, the primary length was found from

$$L_{pri} = 34 \left(W_{a_4} \frac{\sqrt{\theta_4}}{\delta_4} \right)^{0.33}$$

where L is in inches and W_{a_4} is in lbs/sec

or

$$L_{pri} = 112 \left(W_{a_4} \frac{\sqrt{\theta_4}}{\delta_4} \right)^{0.33}$$

where L is in cm. and W_{a_4} is in Kg/sec.

For a geared engine:

$$L_{pri} = 37 \left(W_{a_4} \frac{\sqrt{\theta_4}}{\delta_4} \right)^{0.33} \quad \text{in British units}$$

or

$$L_{pri} = 122 \left(W_{a_4} \frac{\sqrt{\theta_4}}{\delta_4} \right)^{0.33} \quad \text{in metric units}$$

The overall engine length is the sum of the fan case and primary lengths. The fan nozzle variable area range is discussed in Section 4.2.2.

4.2.4 Propulsion Installation for MF Aircraft - Engine installation drawings were made for the three study engine cycles. The nacelles lines were determined on the basis of aerodynamic performance using methods utilized on the DC-9 and DC-10. Both "hard-wall" and treated duct installations were evaluated in the noise level - DOC trade study using the same dimensions for the installations. For the treated installation, acoustical lining was applied to the inlet and exhaust duct walls wherever practical. The 9.2/1.45 and 5.9/1.57 engines had longer fan exhaust ducts than required for aerodynamic performance because of the use of thrust reversers, and, therefore, more area for sound treatment.

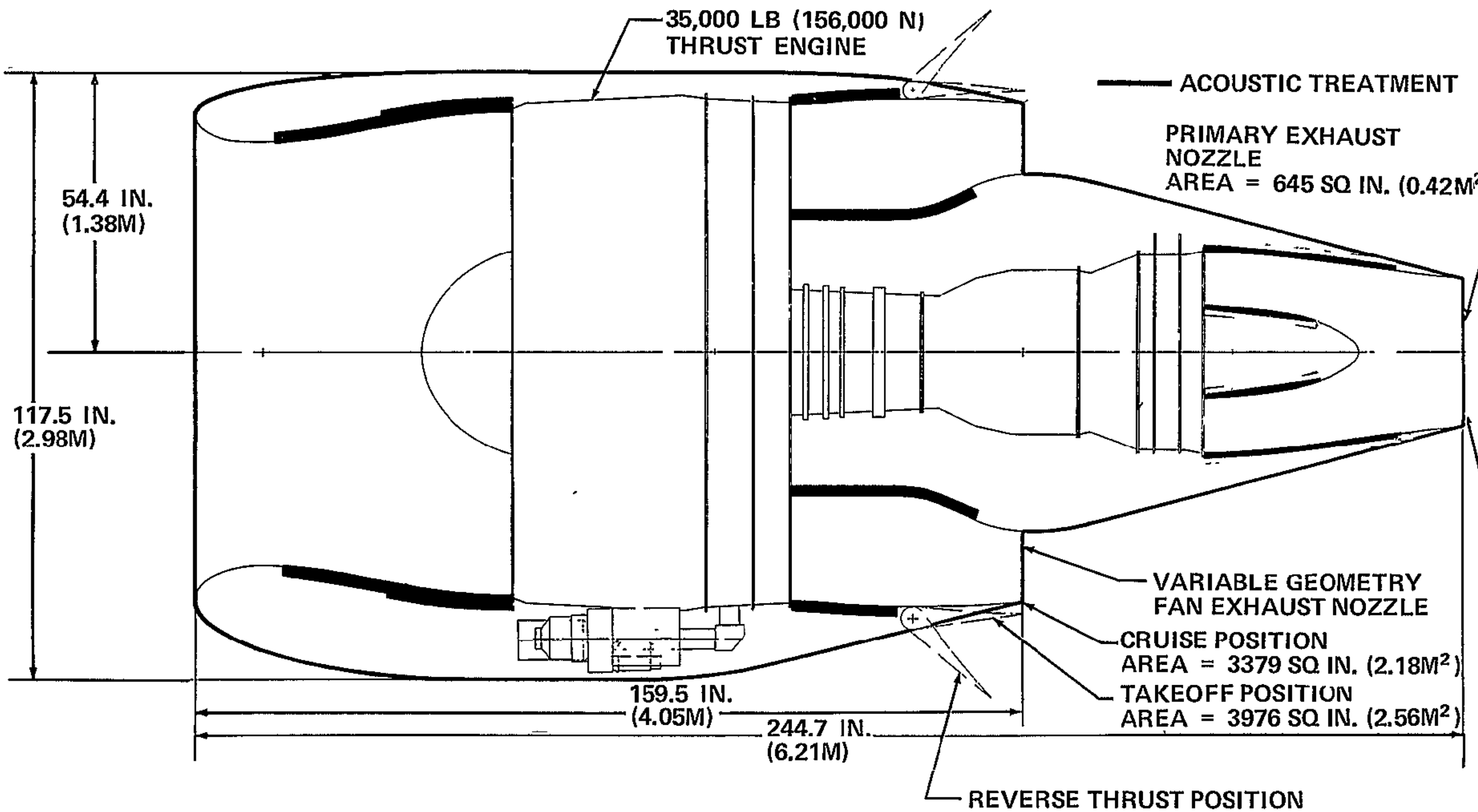
The nacelles were located to attain the best nacelle/wing drag characteristics consistent with avoiding impingement of the hot jet exhaust on the flap surfaces during takeoff and landing.

Engine installations for a mechanical-flap aircraft are shown in Figures 4-20 through 4-25. Figure 4-20 is a vertical section view of the nacelle designed for a 35,000 pound (156,000 N) thrust, variable-pitch fan engine with a fan pressure ratio of 1.32 and a bypass ratio of 12.8. (The installation shown is with acoustic treatment. The untreated case for this engine is identical except the acoustic treatment is deleted.) Figure 4-21 shows the nacelle, pylon, and wing relationships for this installation.

Figure 4-22 is the acoustically-treated installation of the 9.2/1.45 fixed-pitch fan engine at a rated thrust of 35,000 pounds (156,000 N). Figure 4-23 shows the installation on the wing. Figure 4-24 and 4-25 are for a 30,000 pound (133,000 N) engine with a fixed-pitch fan, a FPR of 1.57, and a bypass ratio of 5.9.

NACELLE WITH 12.8/1.32 ENGINE

VARIABLE PITCH FAN



PR3-STOL-2034A

FIGURE 4-20.

INSTALLATION OF 12.8/1.32 ENGINE NACELLE

MECHANICAL FLAP AIRCRAFT

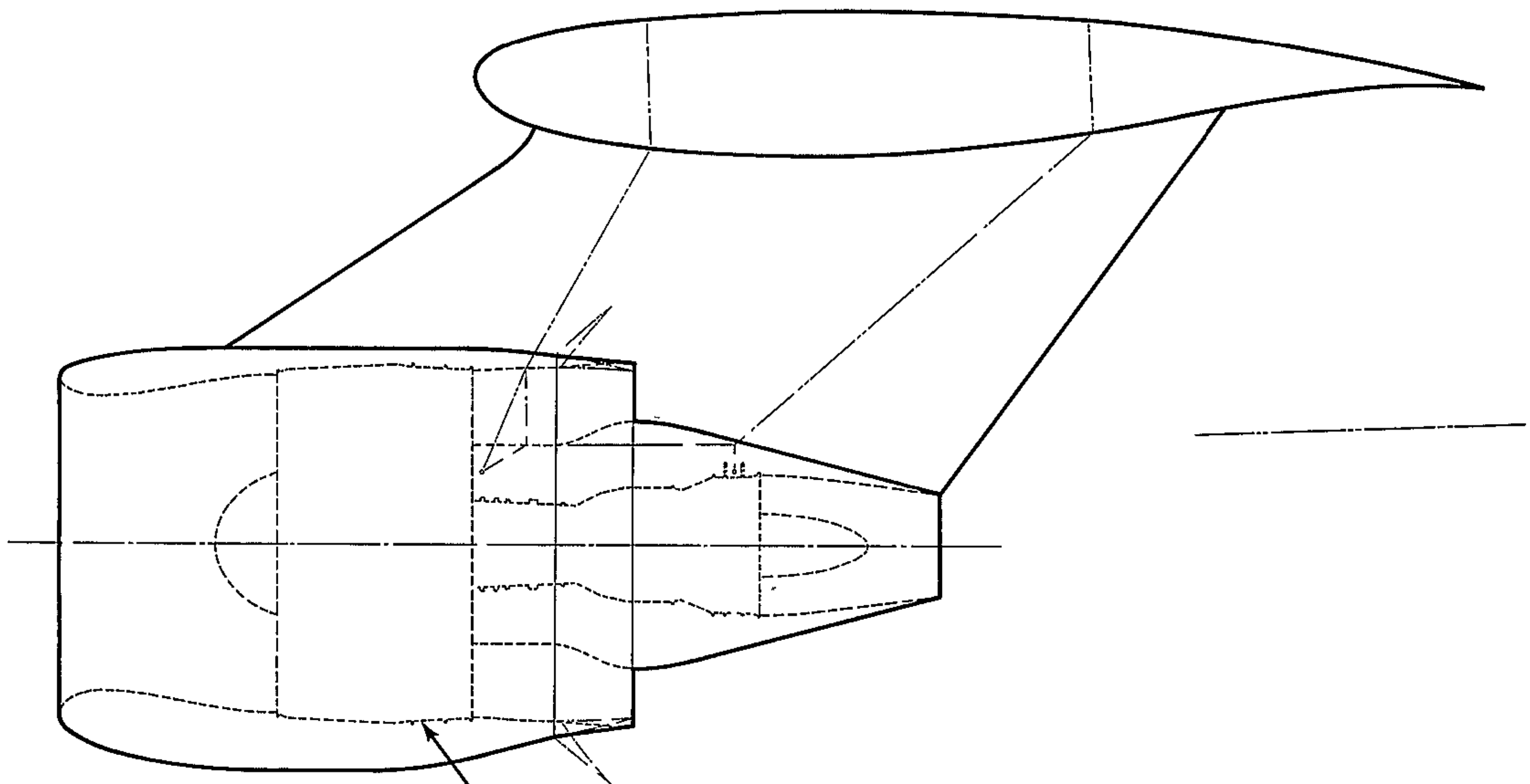


FIGURE 4-21.

NACELLE WITH 9.2/1.45 ENGINE

FIXED PITCH FAN

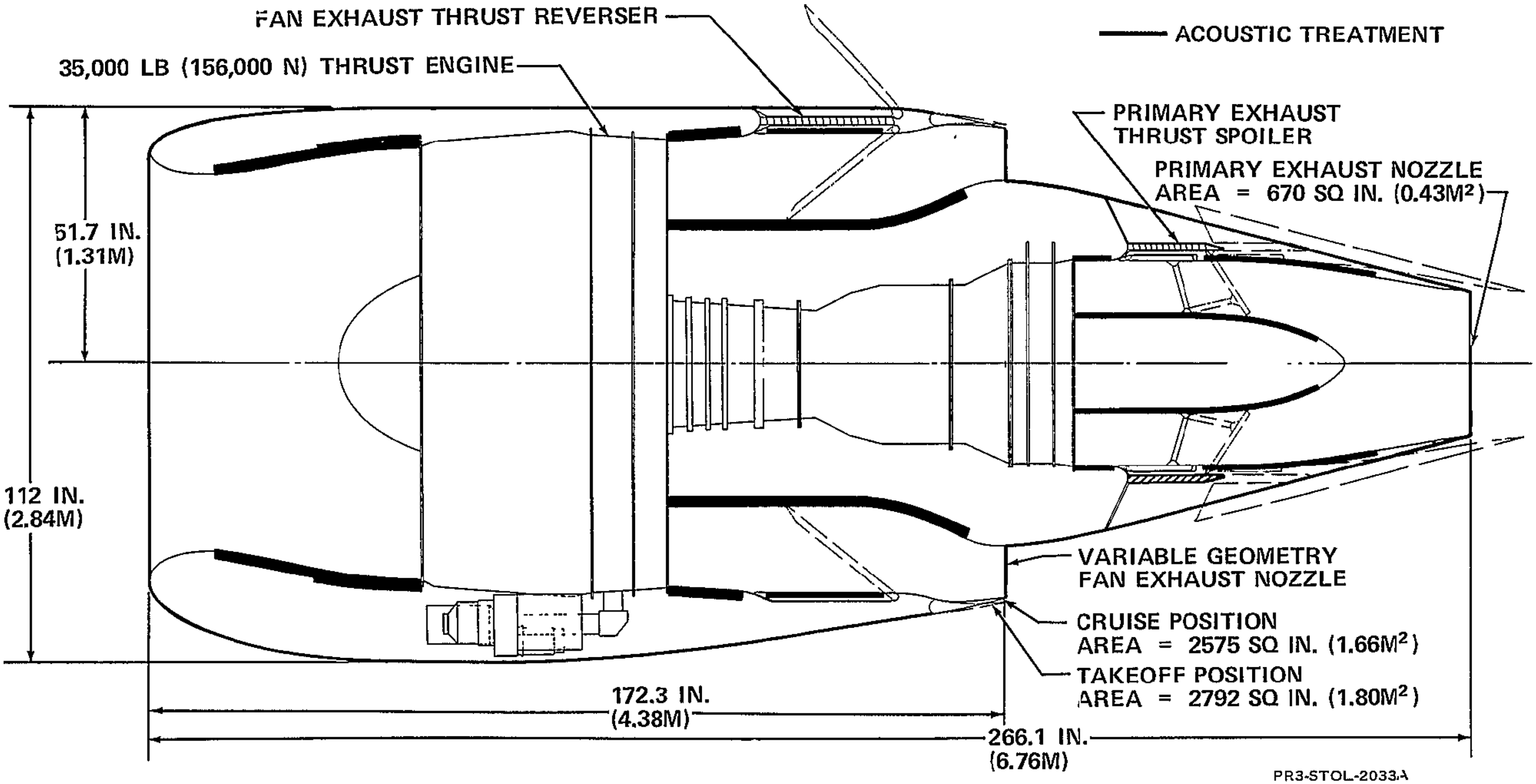


FIGURE 4-22.

INSTALLATION OF 9.2/1.45 ENGINE NACELLE

MECHANICAL FLAP AIRCRAFT

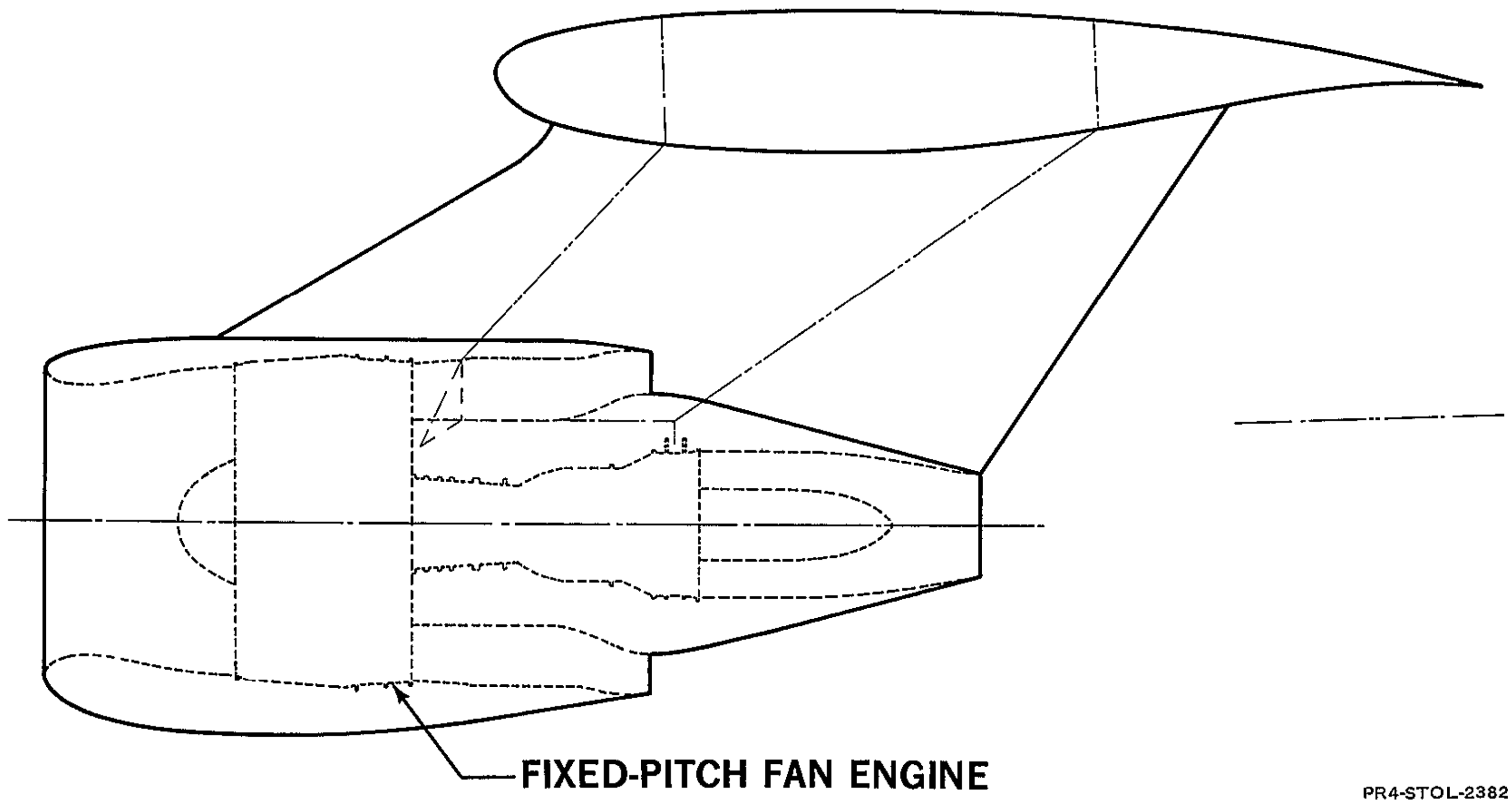


FIGURE 4-23.

NACELLE WITH 5.9/1.57 ENGINE

FIXED PITCH FAN

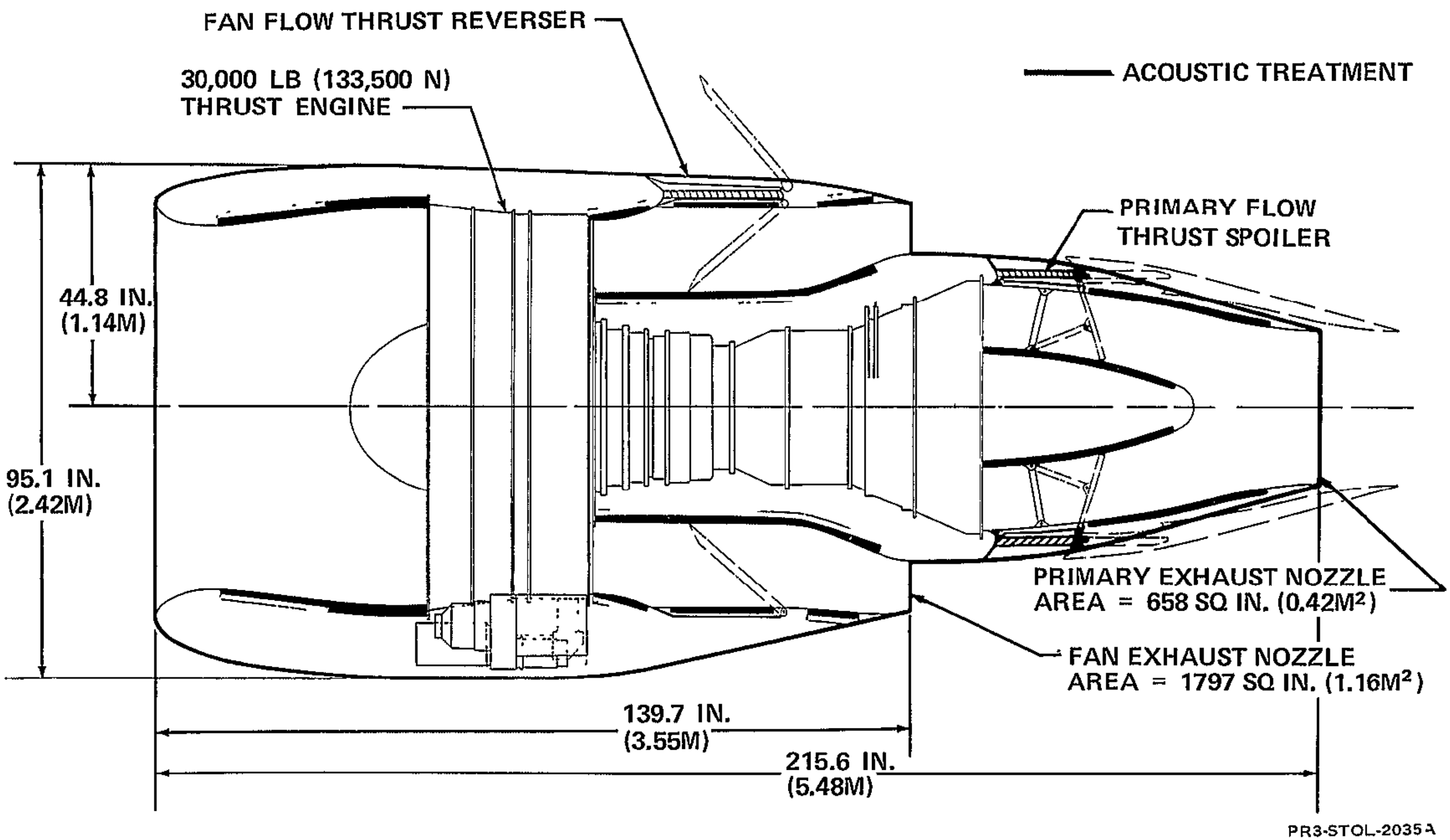
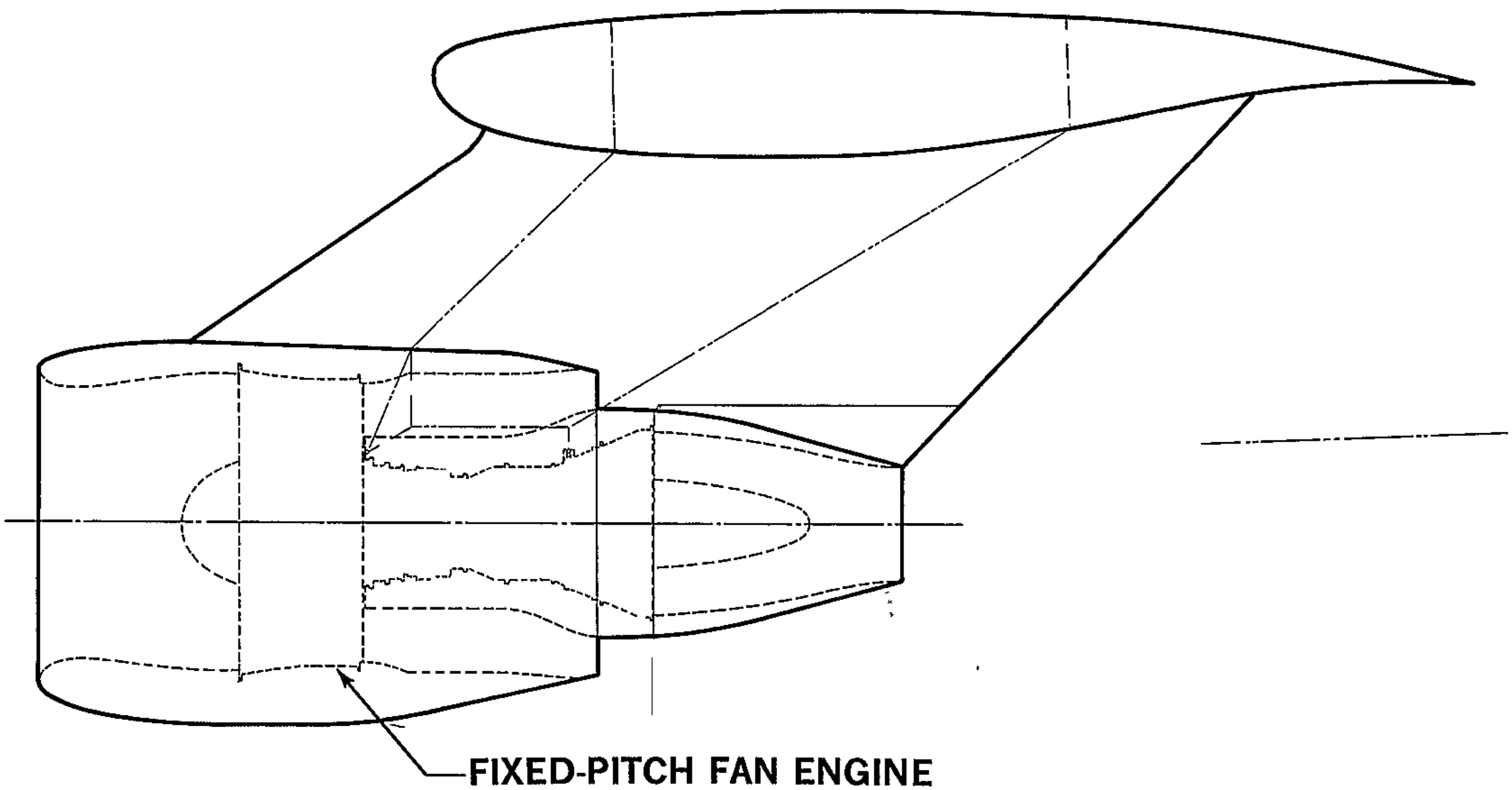


FIGURE 4-24.

INSTALLATION OF 5.9/1.57 ENGINE NACELLE

MECHANICAL FLAP AIRCRAFT



PR4-STOL-2381

FIGURE 4-25.

Performance penalties, which are a function of each nacelle design, were assessed and combined with the engine cycle performance of the 1.32, 1.45 and 1.57 FPR engines. This was accomplished by combining the thermodynamic cycle program (SPEC) with a mathematical description of the installation effects listed below:

- Inlet and exhaust system total pressure losses, including the applicable losses due to acoustic treatment.
- Nacelle freestream drag and scrubbing drag for those external surfaces that are washed by the engine exhaust flow.

The effect on engine thrust and fuel flow for these installation effects is shown in Table 4-7.

4.2.4.1 Engine Inlet Geometry - The engine inlet throat area is sized to give an average throat Mach number of 0.6 at takeoff power at sea level static conditions. The inlet is configured with a leading edge lip thickness that varies from 11 percent at the top to a maximum of 13.7 percent at the bottom. This lip design is based on test results to give acceptable inlet distortion levels at high angles of attack.

4.2.4.2 Engine Inlet Loss - The inlet total pressure loss, shown in Table 4-7, is calculated as flat-plate skin-friction loss on all surfaces. A friction coefficient, 40 percent higher than that for smooth surfaces, was assumed for all acoustically treated surfaces. The increase in loss at high mass flow ratios (takeoff condition) is due to high local velocities

Table 4-7

INSTALLATION LOSSES

Engine Designation	Flight Condition	Alt	M_o	T_o	F_{n_o}	W_{f_o}	Loss Summary	Inlet Recovery $\frac{P_{T2}}{P_{T0}}$	Air Conditioning Bleed	Mechanical Power Extraction	$\frac{\Delta P_{T_{DUCT}}}{P_T}$	$\frac{\Delta P_{T_{PRI}}}{P_T}$	DRAGS D_O	DRAGS D_{FAN}	DRAGS D_{PRI}	F_{N_C} $\Sigma \frac{\Delta F_N}{F_N}$	W_{f_C} $\Sigma \frac{\Delta W_f}{W_f}$
5 9/1 57	T O	0	.117	95°F (35°C)	25,774 lb (114 648 N)	10,818 lb/hr (1.363 kg/s)	Amount	996	1.27 lb/sec (.576 kg/s)	75 HP (56 kW)	0041	007	30 lb (133 N)	455 lb (2024 N)	36 lb (160 N)	24,692 lb (109,835 N)	10,730 lb/hr (1.355 kg/s)
							$\Delta F_N/F_N$	007	011	- 001	003	002	001	018	001	042	
							$\Delta W_f/W_f$	002	004	002	0 0	0 0	0 0	0 0	0 0		008
	Cruise	30,000 ft (9144 m)	7	Std	7,832 lb (34,840 N)	4,758 lb/hr (599 kg/s)	Amount	997	1 27 lb/sec (576 kg/s)	55 HP (41 kW)	0041	007	316 lb (1405 N)	270 lb (1201 N)	24 lb (107 N)	6,924 lb (30,799 N)	4,783 lb/hr (603 kg/s)
							$\Delta F_N/F_N$	007	03	-.008	005	003	041	.035	003	116	
							$\Delta W_f/W_f$	003	004	- 013	0 0	0 0	0 0	0 0	0 0		- 005
9 2/1.45	T O.	0	117	95°F (35°C)	29,822 lb (132,654 N)	10,996 lb/hr (1 385 kg/s)	Amount	996	2 05 lb/sec (93 kg/s)	75 HP (56 kW)	0054	013	39 lb (173 N)	549 lb (2442 N)	20 lb (89 N)	28,122 lb (125,093 N)	10,845 lb/hr (1 366 kg/s)
							$\Delta F_N/F_N$	010	014	002	007	003	001	.019	001	.057	
							$\Delta W_f/W_f$	004	007	003	0 0	0 0	0 0	0 0	0 0		.014
	Cruise	30,000 ft (9144 m)	7	Std	7,790 lb (34,653 N)	4,640 lb/hr (585 kg/s)	Amount	997	2 05 lb/sec (93 kg/s)	55 HP (41 kW)	.0054	013	419 lb (1864 N)	342 lb (1521 N)	12 lb (53 N)	6,427 lb (28,589 N)	4,513 lb/hr (.569 kg/s)
							$\Delta F_N/F_N$	010	042	002	009	005	.058	.047	.002	175	
							$\Delta W_f/W_f$	004	022	001	0 0	0 0	0 0	0 0	0 0		027
12 8/1.32	T O.	0	117	95°F (35°C)	29,358 lb (130,591 N)	9,890 lb/hr (1 246 kg/s)	Amount	.996	2 05 lb/sec (93 kg/s)	75 HP (56 kW)	.0032	.010	41 lb (182 N)	375 lb (1668 N)	24 lb (107 N)	27,832 lb (123,802 N)	9,739 lb/hr (1 227 kg/s)
							$\Delta F_N/F_N$	.010	014	005	005	003	.001	013	001	052	
							$\Delta W_f/W_f$	003	008	004	0 0	0 0	0.0	0.0	0 0		015
	Cruise	30,000 ft (9144 m)	7	Std	7,122 lb (31,680 N)	4,133 lb/hr (.521 kg/s)	Amount	997	2 05 lb/sec (93 kg/s)	55 HP (41 kW)	0032	.010	439 lb (1953 N)	275 lb (1223 N)	14 lb (62 N)	5,862 lb (26,075 N)	3,999 lb/hr (504 kg/s)
							$\Delta F_N/F_N$	011	048	004	007	.004	062	039	002	177	
							$\Delta W_f/W_f$	003	027	002	0 0	0 0	0.0	0.0	0 0		032

NOTES (1) Uninstalled thrust (F_{n_o}) contains the effect of nozzle velocity coefficients (C_v) and nozzle discharge coefficients (C_d), shown in Section 4 2 2

near the inlet leading edge at static conditions and low forward speeds. The method used to estimate the inlet pressure loss has been correlated with test data obtained from wind tunnel and full-scale boundary layer surveys on the inlets of DC-8, DC-9 and DC-10 aircraft.

4.2.4.3 Nacelle External Shape - The maximum nacelle radii are sized to provide engine fan case clearance and to the accommodation of a fan exhaust duct which has been designed for a duct Mach number of 0.45. The nacelle/fan case clearance includes a volume allocation for the engine accessories and engine-mounted airframe system components such as C.S.D. generators, hydraulic pumps and pneumatic system controls and ducting. Size estimates of these components were based upon past experience with airplane requirements on the DC-8, DC-9 and DC-10 production programs.

The core cowl afterbody length is the minimum consistent with keeping the boat-tail angle at a value that prevents compressibility drag.

4.2.4.4 Nacelle External Drag - The drag of the isolated nacelle at the typical cruise condition is included in the installed engine performance. The skin friction coefficient used to calculate drag is a function of the local Reynolds number. Local Reynolds number is calculated for both the freestream cruise condition and the fully expanded exhaust flows for both fan and primary exit conditions. Drag coefficients, D/q, are then calculated for the nacelle and pylon in the three flow regimes; freestream, fan nozzle discharge, and primary nozzle discharge. Depending on the nacelle configuration, the fan cowl and part of the pylon are exposed to freestream flow, while parts of the pylon and engine core cowl are exposed to fan nozzle discharge. Also, nozzle base drag for the fan and primary nozzles is included

in the drag coefficients. Drag values for the three flow regimes are shown in Table 4-7.

4.2.4.5 Exhaust Duct Geometry - The fan duct flow area is sized to maintain duct Mach number below 0.45 through the duct from the engine fan exit to the discharge section. For the 1.32 and 1.45 FPR engines, a variable area is required at the fan nozzle to maintain an efficient match between takeoff and cruise. The area variation is accomplished by the fan cowl trailing edge having actuated flaps which produce varying nozzle exit diameters. The 1.57 FPR engine has a fixed-area fan nozzle. The primary exhaust duct has a center plug shaped to minimize flow losses.

4.2.4.6 Exhaust Duct Losses - The exhaust system losses were evaluated using skin friction calculations for smooth and for acoustically treated walls in the same manner as for the inlet.

4.2.4.7 Accessibility - Access to the engine accessory section, located around the periphery of the engine fan case, is provided by fan cowl doors which are hinged at the top from the pylon structure. The accessory gear box is located on the bottom of the engine fan case since airlines prefer this location over location on the gas generator based on their experience. The benefits are ease of accessibility and improved service life due to the cooler environment.

Engine core case access is provided by splitting the fan duct vertically into half sections which are hinged from the pylon structure. This concept is basically the same as that which has been successful on the DC-10.

4.2.4.8 Thrust Reversing - Reverse thrust is obtained with the 1.32 FPR variable-pitch fan engine by rotating the fan blades into reverse pitch. The effect of this feature upon the overall engine installation is a requirement for the variable-geometry fan nozzle to function as an inlet during reverse (Figure 4-20). The area required is larger than that required for takeoff and cruise. Mechanical designs for engines having variable-pitch fans with fan pressure ratios greater than 1.4 have not yet been established. For these higher fan pressure ratio engines, cascade-type fan reversers were used, as shown in Figures 4-22 and 4-24.

The fan duct thrust reversers shown are fixed-cascade types with external cowl doors that are hinged at the aft end and which can thus be used to assist the cascade vanes in imparting a forward directivity to the fan exhaust flow. In response to the requirement to improve low speed capability for minimum re-ingestion and reverser flow ground-impingement, upward directivity is imparted to the reversed thrust fan exhaust stream by limiting the cascades and external cowl doors to only the top 200 degree portion of the nacelle circumference. Blocker doors which hinge inward from the outer wall of the fan duct at the cascade trailing edge station are used to close off the forward thrust flow path during reverse thrust.

Primary spoilers of the cascade type are also shown. The low engine thrust/takeoff gross weight characteristics of the MF aircraft make it doubtful that sufficient reverse thrust can be attained without spoiling the primary flow.

4.2.4.9 Weight of Engine Installations - Installed engine weight is discussed in Appendix A. Propulsion system weights for the 1.32, 1.45, and 1.57 FPR

engines are itemized in Table A-5.

4.2.5 Engine Performance - Installed engine performance was generated by combining the engine installation effects resulting from each engine nacelle design described in Section 4.2.4 with the airframe demands supplied by the engine.

These additional losses result from engine compressor airbleed and mechanical power extraction. Engine compressor airbleed is used for air conditioning and pressurizing the cabin. Airbleed levels are based on DC-10 required cabin flow rates per passenger.

Mechanical power extraction is based on a statistical study of system requirements in several modes of flight. For all configurations, 150 HP (112 kW) per airplane was used for takeoff conditions, while 110 HP (82 kW) per airplane was used for cruise conditions.

The effect on engine thrust and fuel flow of airbleed and power extraction is shown in Table 4-7.

Installed propulsion system performance data for all significant aircraft operating conditions are shown in Figures 4-26 through 4-31. Performance for takeoff (maximum power) is presented in terms of gross thrust and ram drag in Figures 4-26 through 4-28. Installed fuel flow for any condition can be obtained from Figures 4-29 through 4-31 which show the generalized fuel flow parameter as a function of net thrust and Mach number.

The data shown do not account for the effects of acoustic treatment. The effect of duct wall acoustic treatment on engine thrust is small, and negligible on fuel flow. To account for the effect of wall treatment on engine thrust, the percentage thrust losses listed in Table 4-8 were applied to the basic data shown in Figures 4-26 through 4-31.

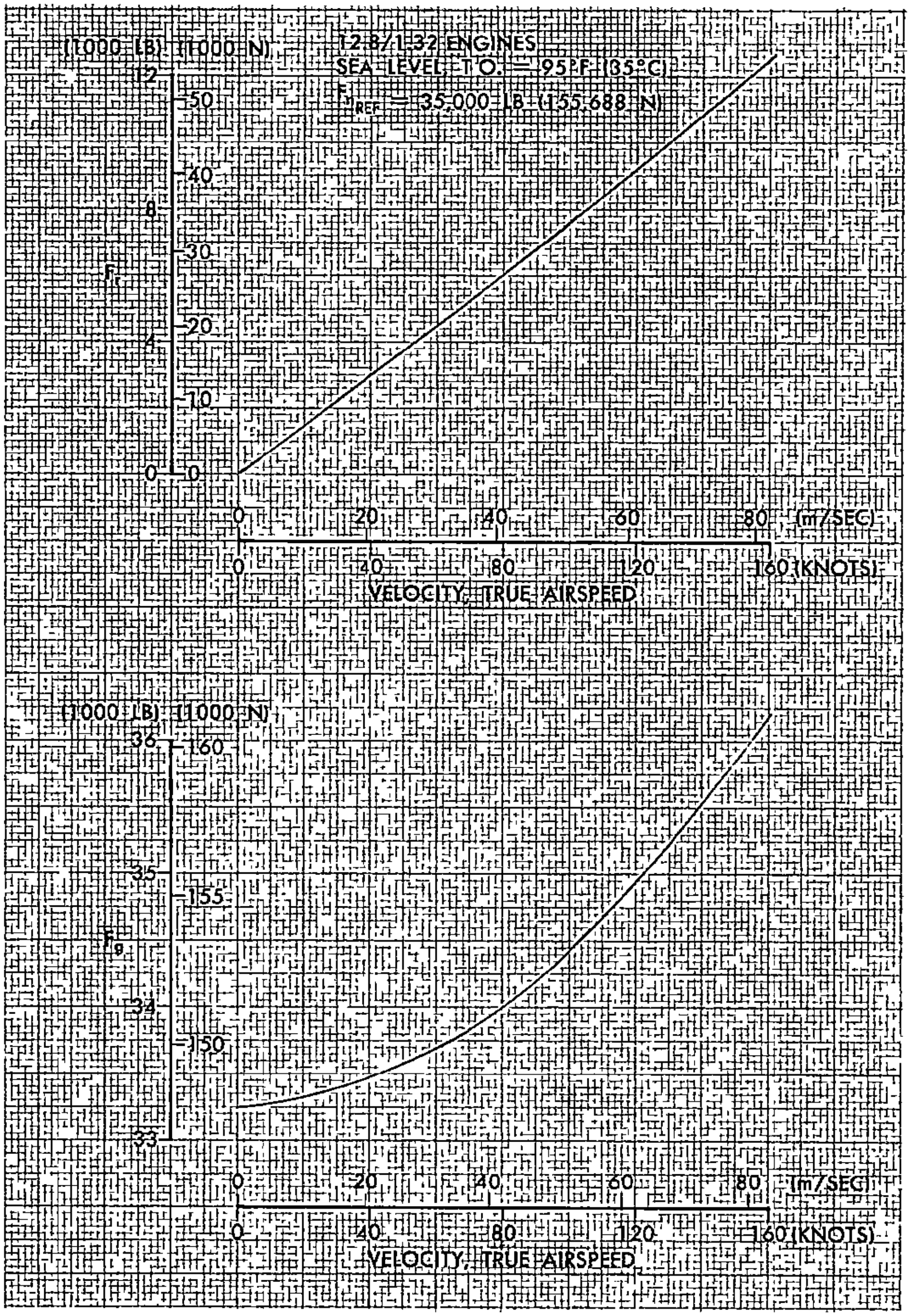


FIGURE 4-26. GROSS THRUST AND RAM DRAG AT TAKEOFF POWER FOR MECHANICAL FLAP AIRCRAFT

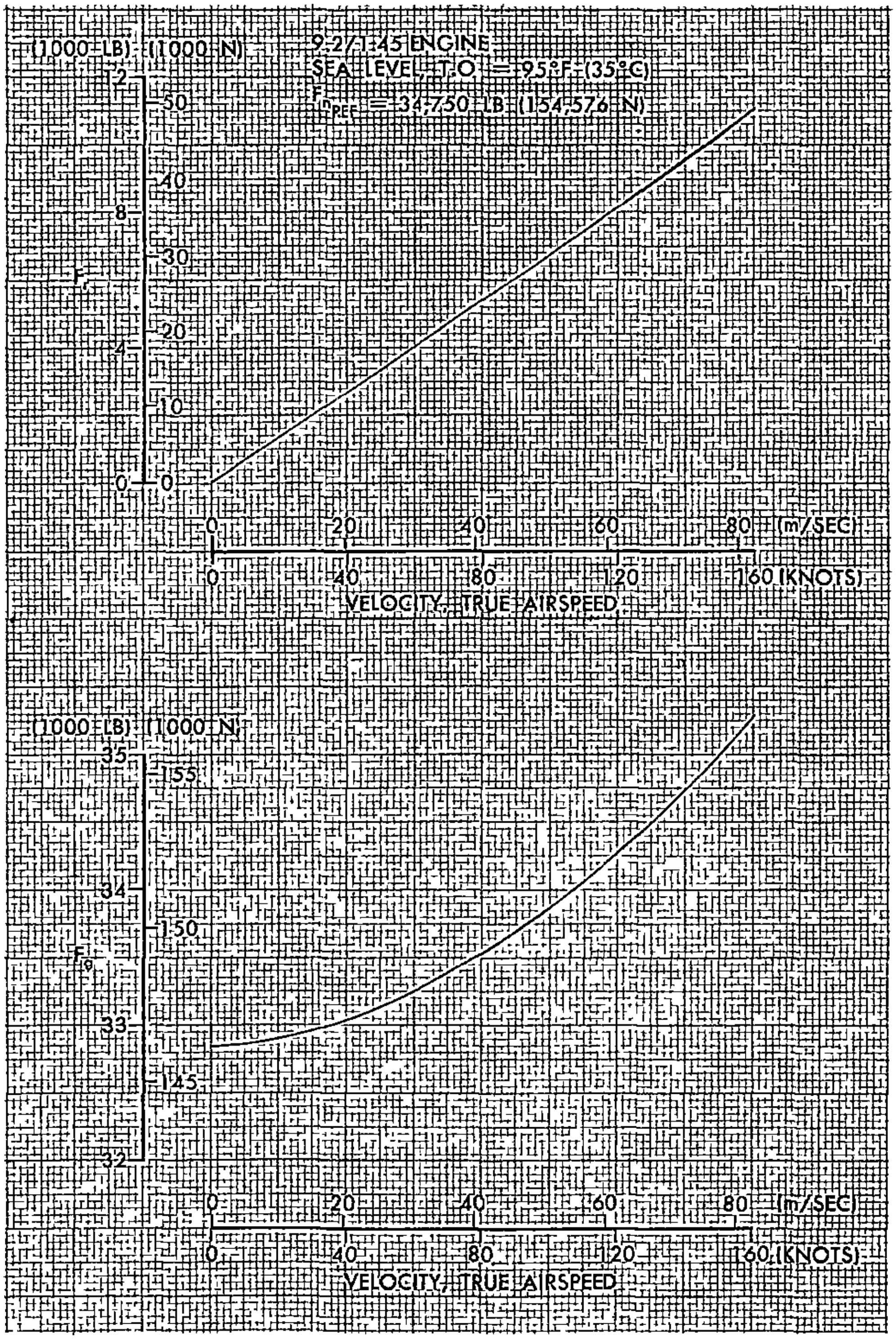


FIGURE 4-27. GROSS THRUST AND RAM DRAG AT TAKEOFF POWER FOR MECHANICAL FLAP AIRCRAFT

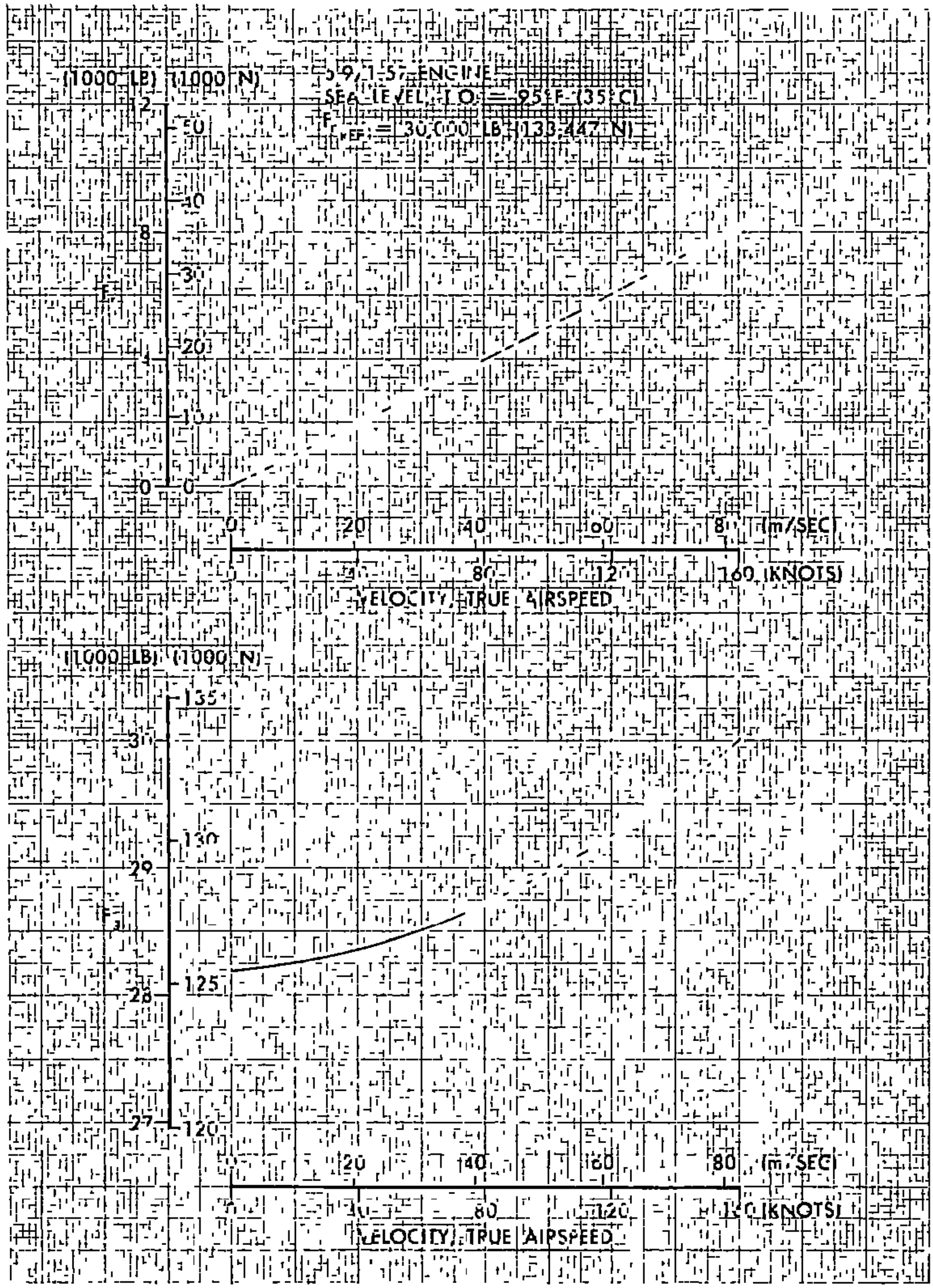


FIGURE 4-28. GROSS THRUST AND RAM DRAG AT TAKEOFF POWER FOR MECHANICAL FLAP AIRCRAFT

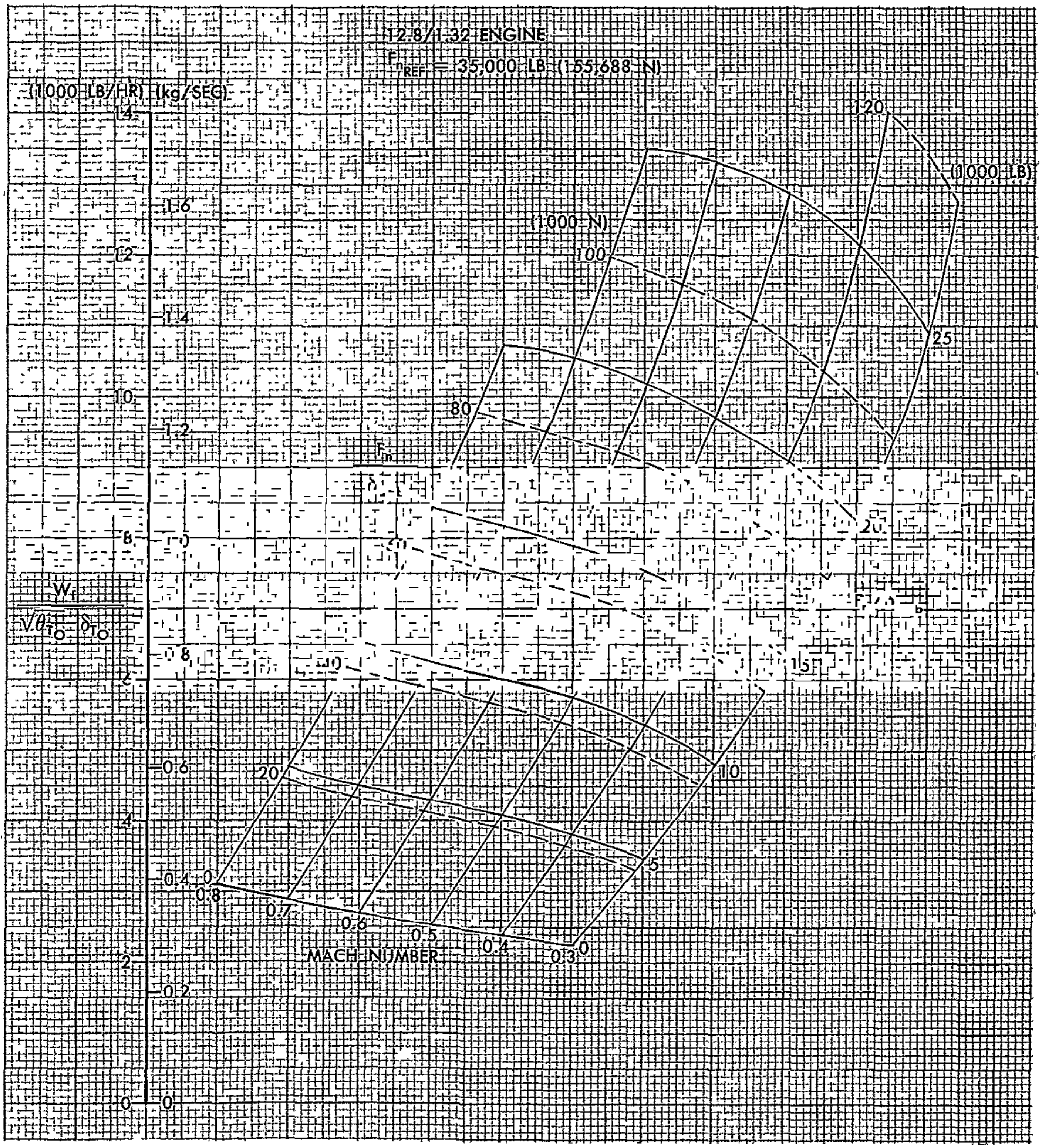


FIGURE 4-29. GENERALIZED NET THRUST AND FUEL FLOW FOR MECHANICAL FLAP AIRCRAFT

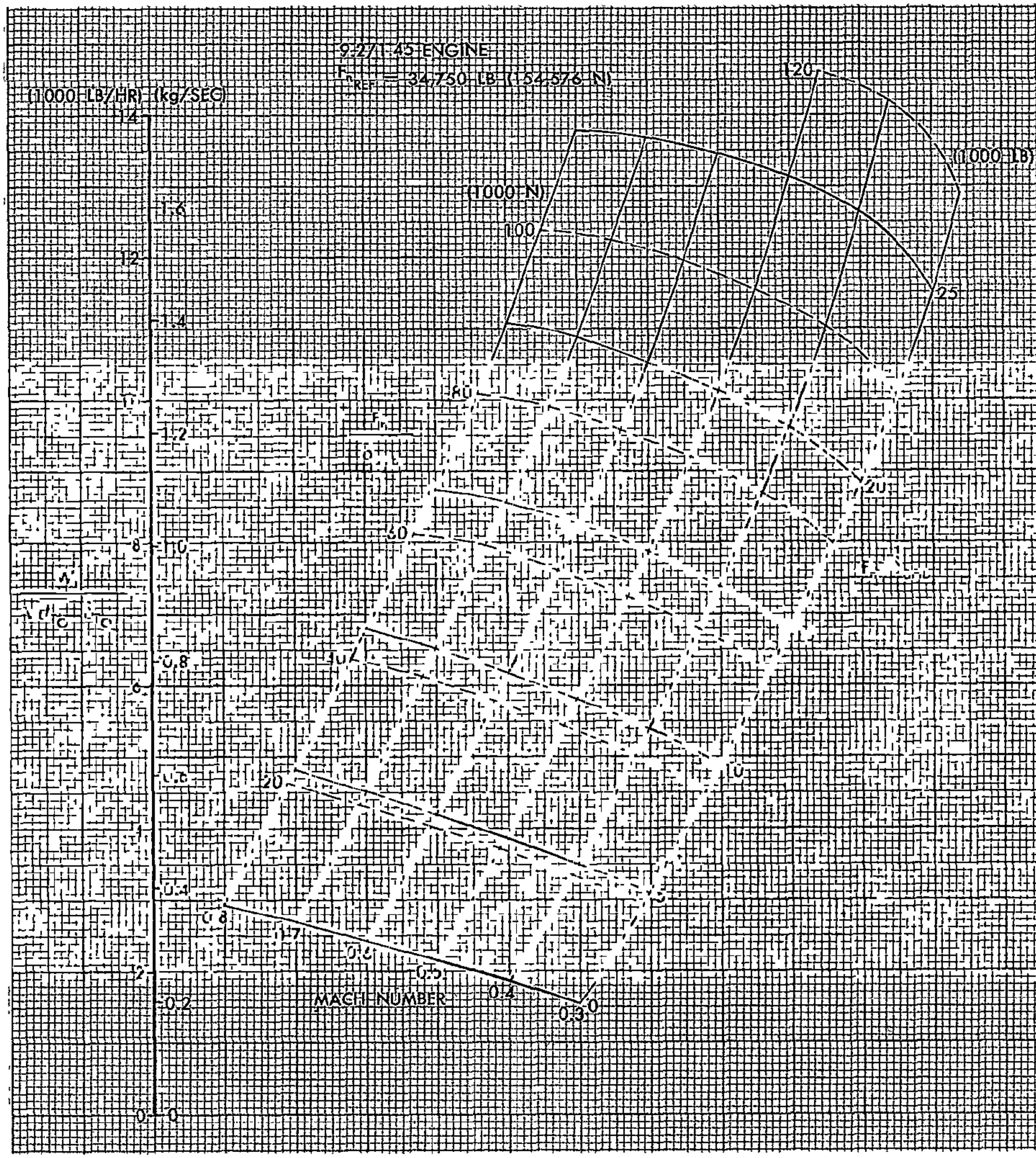


FIGURE 4-30. GENERALIZED NET THRUST AND FUEL FLOW FOR MECHANICAL FLAP AIRCRAFT

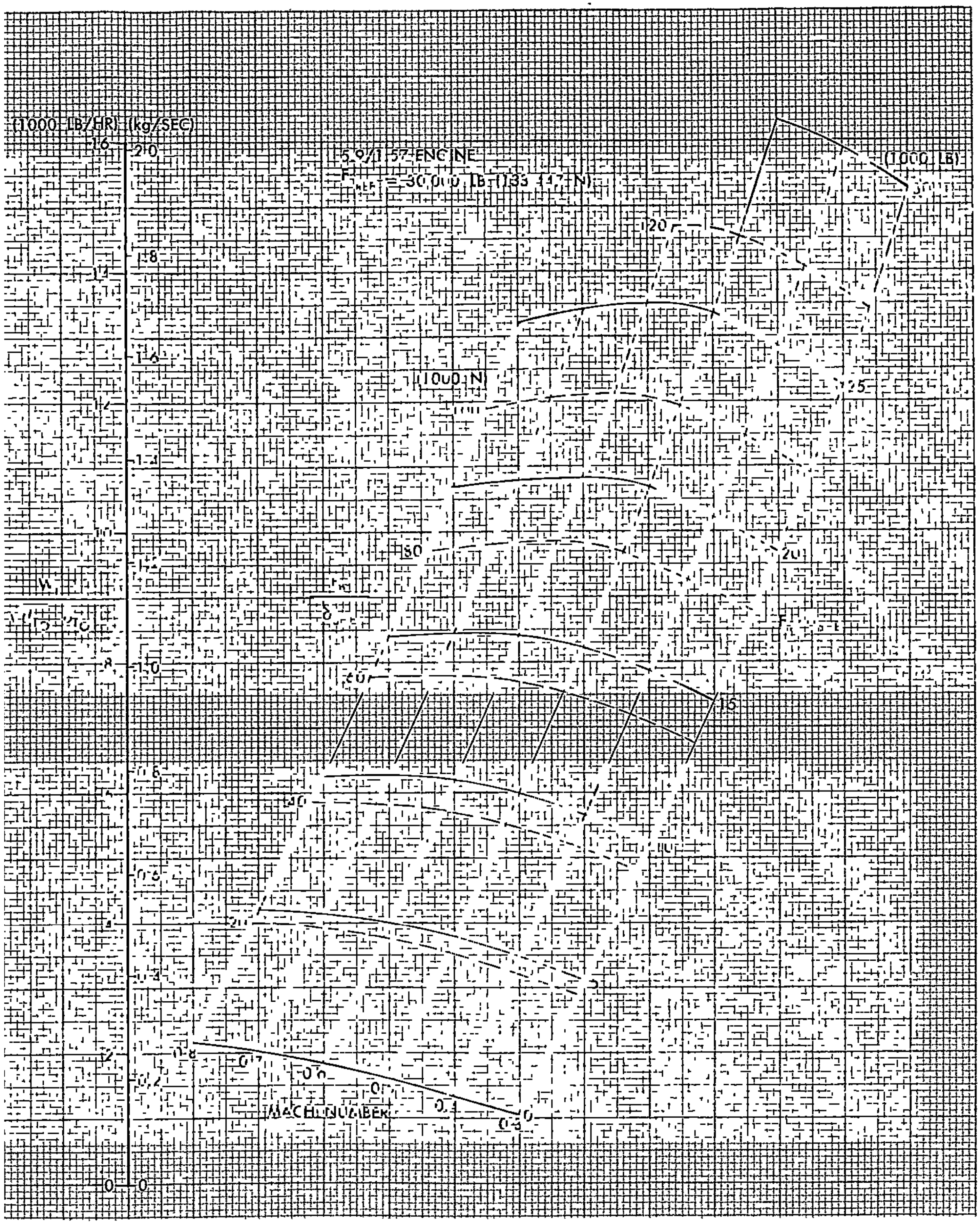


FIGURE 4-31. GENERALIZED NET THRUST AND FUEL FLOW FOR MECHANICAL FLAP AIRCRAFT

TABLE 4-8

Thrust Loss Due to Acoustic Treatment
($\Delta FN/FN$)

Power Setting	Engine Designation 5.9/1.57	9.2/1.45	12.8/1.32
T.O.	.002	.003	.004
All Others	.003	.004	.005

4.2.6 Engine Price Estimates - Estimates of engine prices were made for inputs into the DOC calculations. The method of Reference 5 was used as a base for estimating the effect of thrust on price of a fixed-pitch fan engine. The level of the engine price curve was adjusted to coincide at the 20,000 pound (89,000 N) thrust level with the fixed-pitch engine (PD287-23) used in the acoustic trade study DOC calculations of Reference 1. The price of a variable-pitch fan engine used was 1.154 times that of a fixed-pitch engine of the same level. This factor was obtained as an average for the values used in the NASA QCSEE Study Program in 1972. Figure 4-32 presents the engine price in 1972 dollars per unit of thrust as a function of thrust for both fixed-pitch and variable-pitch fan engines.

Figure 4-32 also shows the results of using the Rand (Reference 5) estimation method for a "Class II" engine*:

$$C_{aver.} = \frac{27.8F^{0.55}\ M^{0.62}\ Q^{0.1} + 0.194\ F^{0.6}\ Q^{0.846}}{Q} \times 1.35 \times 10^{6}$$

where C_{aver} is the average cost in 1972 dollars per engine, with the development

* The referenced report classifies a "Class II" engine as one which contains more steel than titanium and super-alloys. The classification determines the level of cost, but does not substantially affect the variation of cost with thrust, which was the purpose of this comparison.

ENGINE PRICE ESTIMATION

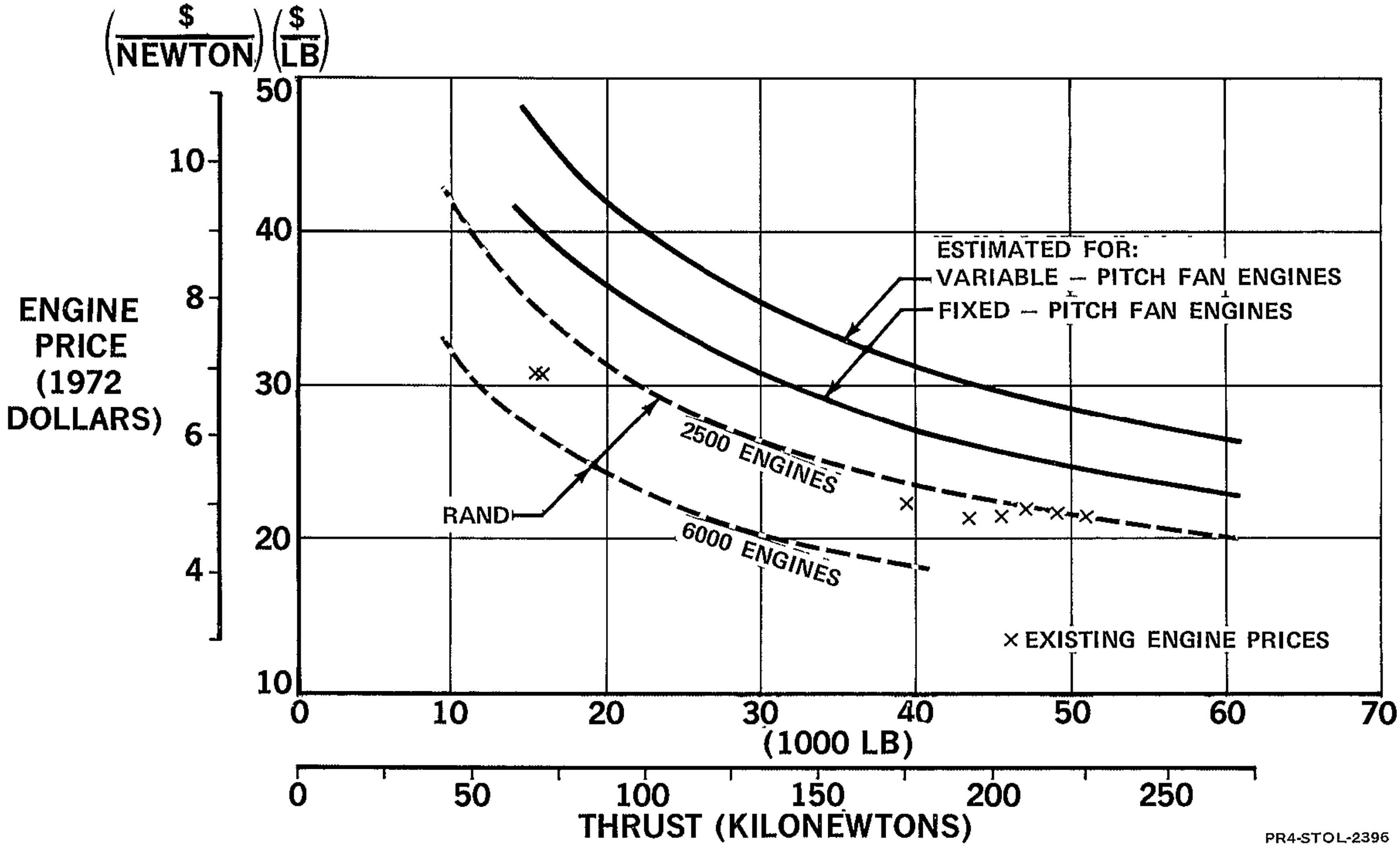


FIGURE 4-32.

cost amortized over Q number of engines, F is the takeoff thrust in thousands of pounds, and the Mach number M was assumed to be 0.85. The factor 1.35 was used to convert from 1969 to 1972 dollars. Prices of some existing engines produced in varying quantities are shown for comparison, and they tend to substantiate the shape of the curves derived by the Rand method.

If F is in kilonewtons, the equation becomes:

$$C_{aver} = \frac{12.24\ F^{0.55}\ M^{0.62}\ Q^{0.1} + 0.0792\ F^{0.6}\ Q^{0.846}\ \times 1.35 \times 10^{6}}{Q}$$

4.3 Aircraft Sizing

A matrix of twelve mechanical-flap aircraft were sized based on the methods and ground rules described in Appendix A.1. This matrix consisted of:

Design Field Length:	3000 ft. (914 m), 4000 ft. (1219 m)
Engine FPR:	1.32, 1.45, 1.57
Acoustic Treatment:	None (hardwall), nacelle wall treatment

A twin-engine configuration was selected for all twelve aircraft based on the results of the mechanical-flap configuration trade study (see Section 3.1). Sizing plots, typical of the aircraft in the matrix, are shown in Figures 4-33 and 4-34 for 3000-foot (914 m) and 4000-foot (1219 m) field length aircraft with 1.32 FPR engines without acoustic treatment. Design points were selected on the basis of minimum DOC which occurs at the W/S and T/W where takeoff and landing performance are equally critical. There is, however, very little penalty in terms of aircraft weight or operating cost associated with engine oversizing (increased T/W).

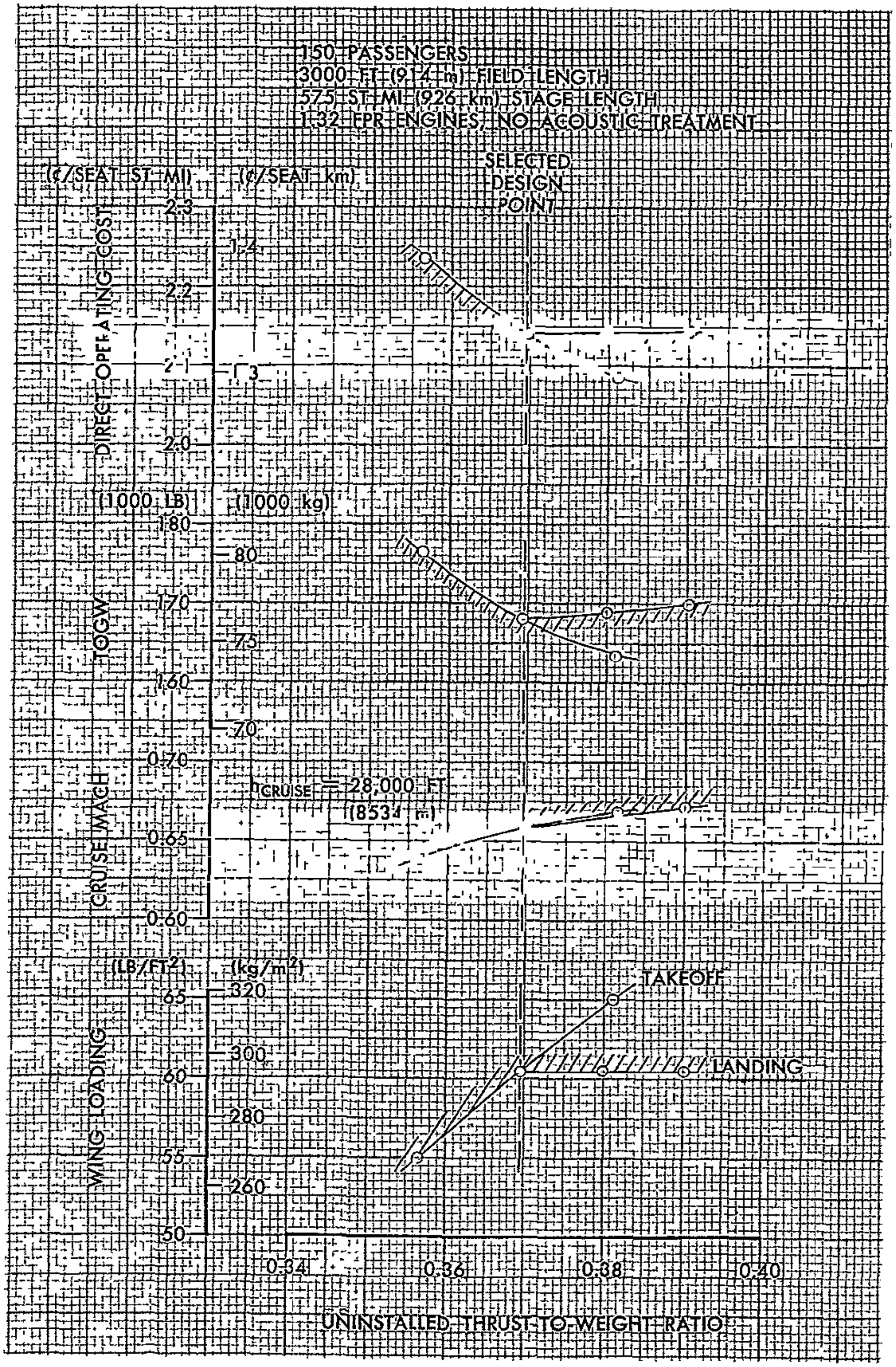


FIGURE 4-33. AIRCRAFT SIZING – M-150-3000

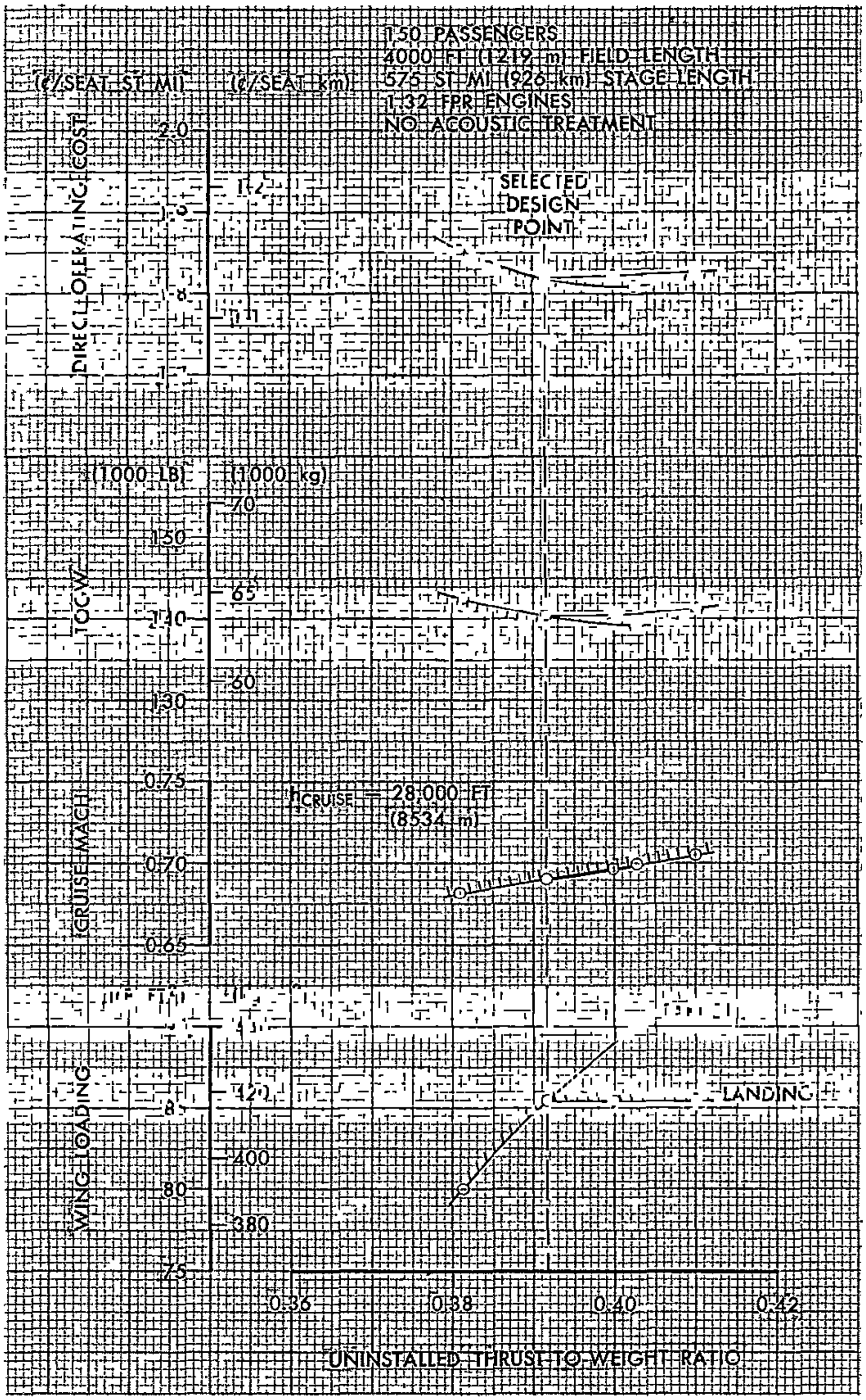


FIGURE 4-34. AIRCRAFT SIZING – M-150-4000

A summary of the aircraft performance characteristics for the twelve aircraft are shown in Tables 4-9 and 4-10. A noticeable increase in Mach number capability is associated with higher engine FPR. This is due to the lower thrust lapse rate of the higher FPR engines. There is also very little penalty in terms of either weight or DOC due to the use of engine nacelle wall acoustic treatment. This level of treatment does not add significantly to engine installation weights nor has much impact on engine thrust and SFC.

Figure 4-35 shows the impact of engine FPR on direct operating cost and aircraft fuel consumption for a 575 statute mile (926 km) stage length. Reducing FPR from 1.57 to 1.32 produces a reduction in fuel usage of 10 to 12 percent for the 3000-foot (914 m) and 4000-foot (1219 m) mechanical-flap aircraft configurations. Fuel consumption for the 4000-foot (1219 m) field length mechanical-flap aircraft is 20 percent lower than for the 3000-foot (914 m) field length vehicle.

The DOC for the 4000-foot (1219 m) field length aircraft with 1.57 FPR engines is approximately 4 percent lower than the DOC for the aircraft with 1.32 FPR engines based on a fuel price of 12 cents per gallon (31.7 $\$/m^3$). Figure 4-35 also shows that higher priced fuel reduces the advantage of the high FPR engines. With the fuel price at 24 cents per gallon (63.4 $\$/m^3$) the DOC advantage of the aircraft with 1.57 FPR engines over that with 1.32 FPR engines is reduced to approximately 3 percent.

TABLE 4-9

ACOUSTIC TRADE STUDY AIRCRAFT SIZING

Twin Engine Mechanical Flap Configuration
3000 Foot (914 m) Field Length

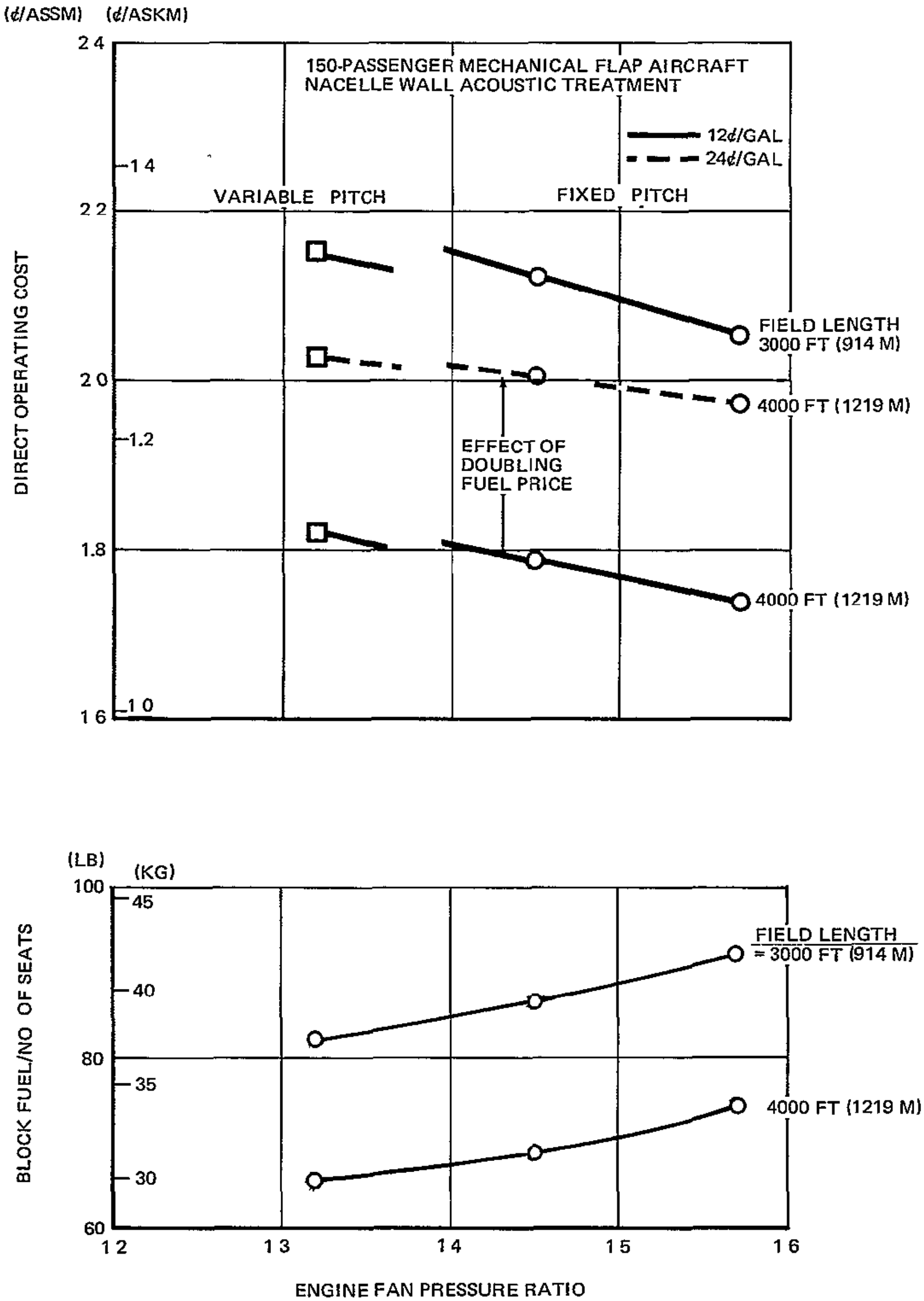
Engine FPR		1.32	1.45	1.57	1.32	1.45	1.57
Engine Treatment		None	None	None	Wall	Wall	Wall
Gross Weight	Lb (kg)	167,900 (76,200	172,900 (78,400)	172,100 (78,100)	168,300 (76,300)	173,200 (78,600)	172,300 (78,200)
Wing Area	Ft^2 (m^2)	2,775 (257.8)	2,858 (265.5)	2,844 (264.2)	2,782 (258.4)	2,863 (266.0)	2,848 (264.6)
Thrust/Engine	Lb (N)	31,050 (138,100)	31,330 (139,400)	30,570 (136,000)	31,240 (139,000)	31,490 (140,100)	30,680 (136,500)
W/S	Lb/Ft^2 (kg/m^2)	60.5 (295.4)	60.5 (295.4)	60.5 (295.4)	60.5 (295.4)	60.5 (295.4)	60.5 (295.4)
T/W		0.370	0.362	0.355	0.371	0.364	0.356
OEW	LB (kg)	120,590 (54,700)	124,710 (56,570)	122,790 (55,700)	120,890 (54,840)	124,930 (56,670)	122,940 (55,770)
AR		8.7	8.7	8.7	8.7	8.7	8.7
M_{cr}		0.66	0.68	0.74	0.66	0.68	0.74
H_{cr}	Ft (m)	28,000 (8,534)	30,000 (9,144)	30,000 (9,144)	28,000 (8,534)	30,000 (9,144)	30,000 (9,144)
DOC @ 575 St. Mi. (926 km)	¢/ASSM (¢/ASKM)	2.15 (1.34)	2.12 (1.32)	2.05 (1.27)	2.15 (1.34)	2.12 (1.32)	2.06 (1.28)

Table 4-10

ACOUSTIC TRADE STUDY AIRCRAFT SIZING

Twin Engine Mechanical Flap Configuration
4000 Foot (1219 m) Field Length

Engine FPR		1.32	1.45	1.57	1.32	1.45	1.57
Engine Treatment		None	None	None	Wall	Wall	Wall
Gross Weight	Lb (kg)	140,300 (63,600)	144,000 (65,300)	143,500 (65,100)	140,600 (63,800)	144,200 (65,400)	143,600 (65,100)
Wing Area	Ft^2 (m^2)	1,641 (152.4)	1,684 (156.4)	1,678 (155.9)	1,644 (152.7)	1,687 (156.7)	1,679 (156.0)
Thrust/Engine	Lb (N)	27,490 (122,300)	27,540 (122,500)	26,780 (119,100)	27,660 (123,000)	27,670 (123,100)	26,870 (119,500)
W/S	Lb/Ft^2 (kg/m^2)	85.5 (417.4)	85.5 (417.4)	85.5 (417.4)	85.5 (417.4)	85.5 (417.4)	85.5 (417.4)
T/W		0.392	0.383	0.373	0.393	0.384	0.374
OEW	Lb (kg)	96,200 (43,640)	99,060 (44,930)	97,470 (44,210)	96,400 (43,730)	99,210 (45,000)	97,550 (44,250)
AR		8.7	8.7	8.7	8.7	8.7	8.7
M_{cr}		0.69	0.71	0.77	0.69	0.71	0.77
H_{cr}	Ft (m)	28,000 (8,534)	30,000 (9,144)	30,000 (9,144)	28,000 (8,534)	30,000 (9,144)	30,000 (9,144)
DOC @ 575 St. Mi. (926 km)	¢/ASSM (¢/ASKM)	1.82 (1.13)	1.79 (1.11)	1.73 (1.07)	1.82 (1.13)	1.79 (1.11)	1.74 (1.08)



DOC AND FUEL CONSUMPTION COMPARISON

FIGURE 4-35.

4.4 Acoustic Analysis

4.4.1 Aircraft Noise Definition - Aircraft noise can be broadly classified into three categories; noise produced by the turbulence associated with the passage of a large body (the aircraft) through the ambient air, propulsive noise produced by the aircraft engines and, in the case of an EBF aircraft, propulsive-lift-system (PLS) noise produced by directing the engine exhaust over or under the wing and flap surfaces to augment the lift characteristics of the aircraft. Of these three components the latter two are considered the most important for STOL type aircraft.

Noise from a turbofan engine can be subdivided into internally generated high-frequency turbomachinery noise and low-frequency core noise produced by the combustion process, and externally generated jet noise produced by the turbulent mixing of the high velocity exhaust gases with the ambient air. Noise from propulsive-lift systems is produced by the direct impingement of the engine exhaust gases on the wing and flap surfaces. Internally generated turbomachinery noise can usually be suppressed by the installation of acoustic materials in the engine nacelle, whereas jet noise and PLS noise are not easily suppressed.

4.4.2 Source Noise Prediction and Suppression

4.4.2.1 Engine Noise Prediction - Engine source noise was predicted using the Douglas developed Quick-Response Engine Source Noise (QRESN) procedure. This procedure, based on ground static and flight test data, uses basic engine operating parameters to predict the peak perceived noise (PNL) on a sideline produced by the engine fan, core, turbine and jet exhaust. The peak inlet and peak aft radiated noise on a sideline is calculated by the

logarithmic summation, on a PNL basis, of the component noise levels, taking into account the directivity of the noise of each component. Engine noise on an EPNL basis was calculated as the peak PNL on a sideline less a duration factor which varies with the aircraft type, distance to the aircraft and airspeed. The duration factor was based on predicted and measured flyover noise data. The methodology for the QRESN procedure is explained in Appendix C-1.

Adjustments were made to the predicted component noise levels based on comparisons of extensive ground static and aircraft flyover noise data. These comparisons indicate an adjustment of -4 dB to the fan inlet radiated noise, when airborne, to account for the reduction of inlet duct airflow distortion and turbulence.

A -1.5 dB technology factor was applied to each engine component noise level to account for estimated improvements in jet engine design which will lead to lower source noise levels. The 1.5 dB improvement is believed to be reasonable as engine acoustic technology development is continued into the 1980 time period. Adjustments for ground attenuation (EGA) and fuselage shielding were based on SAE ARP 1114. For the trade study estimates it was assumed that the peak noise on a 500-foot (152 m) sideline would occur after liftoff when the aircraft reached a 100 foot height. This resulted in an adjustment of -3.0 dB for ground attenuation and fuselage shielding.

4.4.2.2 Turbomachinery Noise Suppression - Internally generated, turbomachinery noise may be suppressed by the use of acoustic materials within the engine nacelle. The specific type of acoustic material for each application requires knowledge of the spectral characteristics of the turbomachinery noise to be suppressed. Since the source noise levels were predicted on a PNL basis, the exact nature of the acoustic materials will not

be specified. Instead, the preliminary design chart shown in Figure 4-36 was used to determine the suppression, on a PNL basis, obtained by a given amount of unspecified nacelle acoustic treatment. This chart was developed from the results of numerous noise suppression tests on JT3D, JT8D, JT9D, and CF6 engines. The abscissa, in Figure 4-36, is the average ratio, for a given treated duct, of the length of treatment (L) to the duct-passage height (H). It can be seen that the attenuation correlates well with the average L/H ratio.

Adjustments were made to account for estimated improvements in acoustic materials design which would result in more noise suppression for a given amount of nacelle acoustic treatment. These adjustments for improved technology assumed that the suppression obtained by a given amount of advanced technology treatment would be equivalent to the suppression obtained by adding 30 percent more of today's nacelle acoustic treatment. The amount of nacelle acoustic treatment was restricted to available space within the existing engine nacelle walls. For the EBF aircraft the nacelle treatment configuration is the wall treatment configuration defined in the Final Report, Volume II, of the NASA Short-Haul Systems Study (Reference 1). The nacelle treatment configurations for the MF trade study engine cycles are shown in Figures 4-20, 4-22, and 4-24. Note that these nacelles were designed for aerodynamic performance. Additional noise reduction could be achieved by lengthening the inlet and exhaust ducts to increase the amount of acoustic treatment.

4.4.2.3 Propulsive-Lift-System (PLS) Noise Prediction - Noise produced by the EBF propulsive-lift system was predicted using the Douglas developed Quick Response Propulsive-Lift System (QRPLS) procedure. This procedure was developed by analyses of numerous sources of static test data. The procedure uses basic aircraft operating parameters to predict the maximum PLS noise on

PRELIMINARY DESIGN CHART FOR ACOUSTICALLY TREATED INLET AND DISCHARGE DUCTS

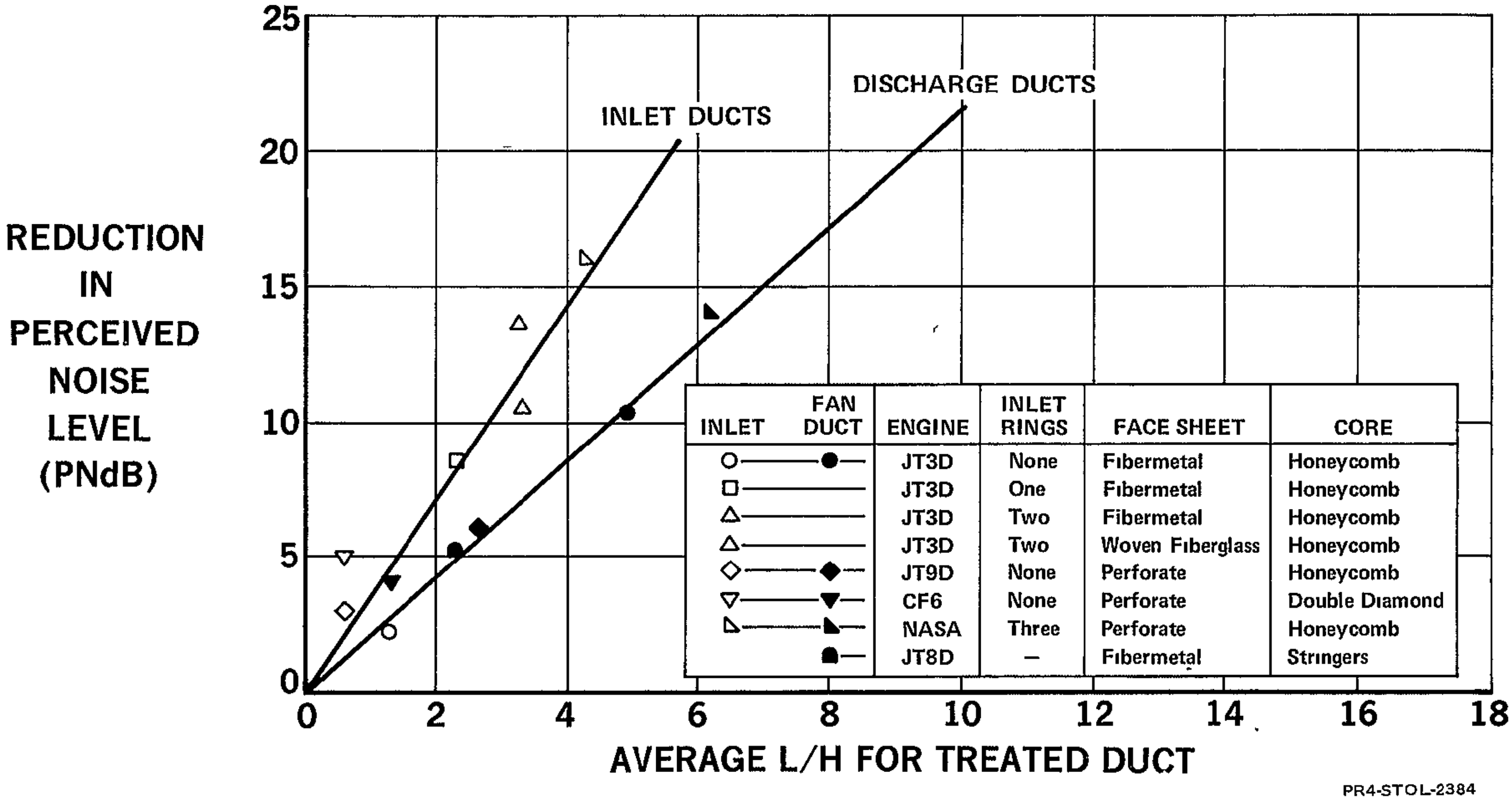


FIGURE 4-36.

a sideline, both on a PNL and EPNL basis. The methodology and background for this procedure is explained in Appendix C-1.

Since propulsive lift is a relatively new concept, a -3.0 dB technology factor was applied to allow for estimated future advances in PLS technology. For the trade study estimates an adjustment of -3 dB for ground attenuation (EGA) and fuselage shielding was based on SAE ARP 1114. Aircraft noise was calculated as the logarithmic summation of engine noise and PLS noise on both a PNL and EPNL basis.

4.4.3 Externally-Blown-Flap Aircraft - During the NASA STOL Short-Haul Systems Study (Reference 1), a trade study was conducted to determine the effect of engine cycle characteristics and degree of acoustic treatment on aircraft sizing, economics and noise level for a 150-passenger, 3000-foot (914 m) field length EBF aircraft. Since improved noise prediction procedures have been developed since that study was performed, the noise estimates made for the three EBF engine cycles were updated. The revised takeoff noise levels, on 500-foot (152 m) sideline, are shown in Table 4-11. Shown in this figure are the component noise levels in terms of PNL, with and without nacelle acoustic treatment, the resultant peak inlet radiated PNL, peak aft radiated PNL, and estimated peak EPNL on a 500-foot (152 m) sideline. The revised estimates were based on the engine characteristics given in Table 4-12. Figure 4-37 is a plot relating EPNdB on a 500-foot (152 m) sideline to direct operating cost for the three EBF trade study engine cycles.

From the NASA STOL System Study the engine cycle selected for the E-150-3000 baseline aircraft had a FPR = 1.25. The nacelle acoustic treatment was increased over that of the trade study aircraft, and the revised EPNL on a 500-foot (152 m) sideline for the final design version of this aircraft, as used in this study, is estimated to be 97 EPNdB. The acoustic

TABLE 4-11

500-FT SIDELINE NOISE COMPARISON

EXTERNALLY BLOWN FLAP AIRCRAFT 150 PASSENGERS

3000 FT (914 m) FIELD LENGTH

100 KNOTS TAKEOFF THRUST, 18-DEGREE FLAPS

	FPR = 1.25			FPR = 1.32			FPR = 1.57		
NOISE SOURCE	UNTRTD	L/H	TRTD	UNTRTD	L/H	TRTD	UNTRTD	L/H	TRTD
FAN INLET PNL	96.5	1.0	92.0	99.0	1.1	94.0	106.5	1.2	101.0
FAN EXHAUST PNL	104.0	1.7	99.0	106.5	1.9	101.0	109.0	4.6	96.0
TURBINE PNL	93.0	2.6	86.0	93.5	1.8	88.5	95.5		95.5
CORE PNL	81.5		81.5	81.5		81.5	96.5		96.5
JET AND FLAP PNL	90.5		90.5	94.0		94.0	107.0		107.0
PEAK INLET PNL	98.0		94.0	100.5		96.5	109.0		106.5
PEAK AFT PNL	104.5		100.0	107.0		102.0	111.5		108.0
EPNL	103.0		98.5	105.5		101.0	111.0		108.5

TECHNOLOGY AREA	TECHNOLOGY FACTOR
JET-FLAP NOISE	–3 dB
FAN, TURBINE AND CORE NOISE	–1.5 dB
ACOUSTIC TREATMENT	1.3 x (L/H) 1973

INCLUDES SHIELDING AND EGA PER SAE ARP 1114 FOR 100-FOOT ALTITUDE

PR4-STOL-2391

treatment configuration for the final design aircraft is shown in Figure B-1 of Appendix B-1.

TABLE 4-12

ENGINE CHARACTERISTICS FOR ACOUSTICS STUDY

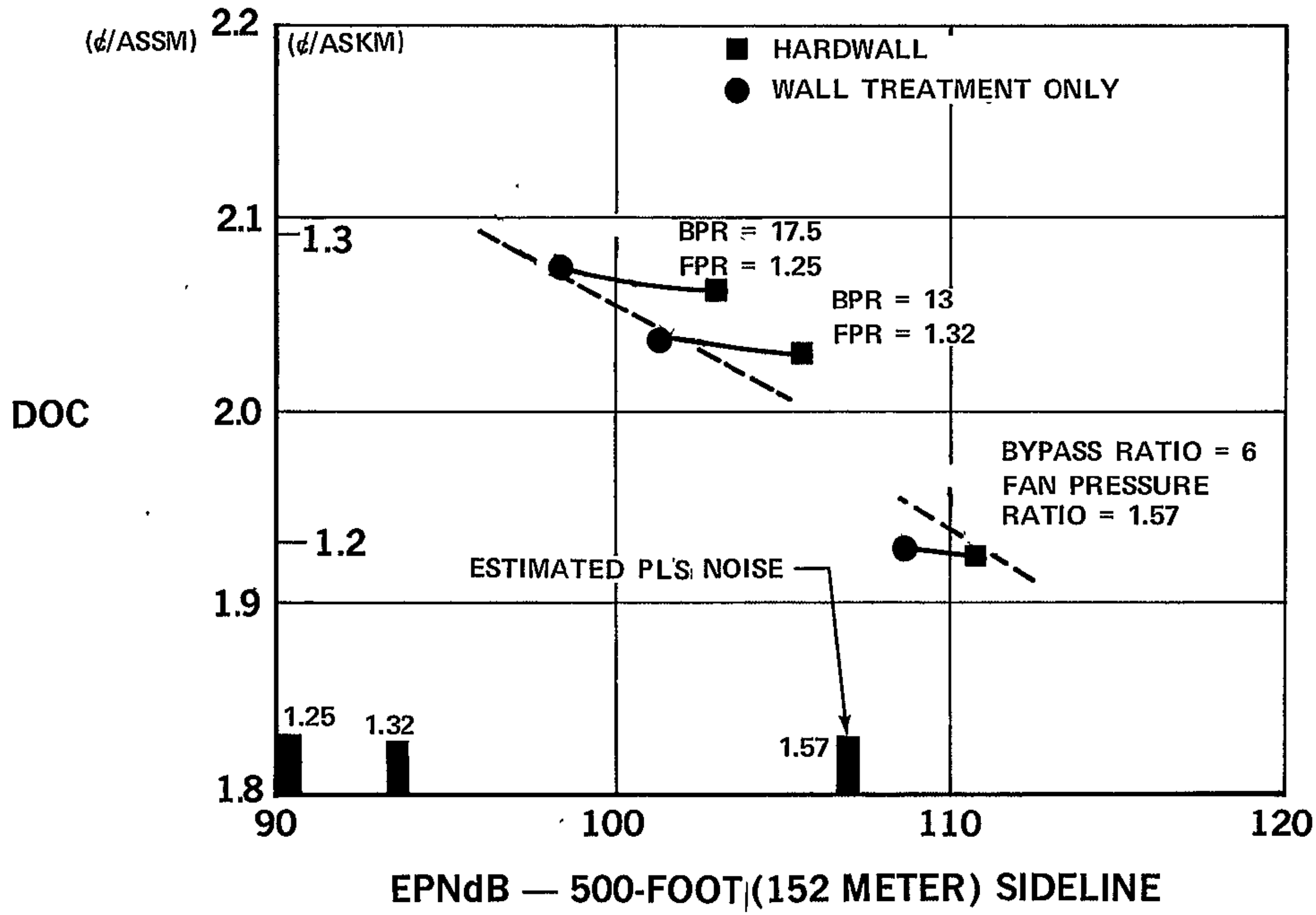
Engine Type	Variable-Pitch	Variable-Pitch	Fixed-Pitch
Fan Pressure Ratio	1.25	1.32	1.57
Bypass Ratio	17	13	6
Wa_{fan}, lbs/sec (kg/sec)(1)(2)	969 (440)	863 (391)	570 (259)
V_{fan}, ft/sec (m/sec)(2)	655 (200)	732 (223)	939 (286)
Wg_{pri}, lbs/sec (kg/sec)(1)(2)	57 (26)	63 (28.5)	98 (44.5)
V_{pri}, ft/sec (m/sec)(2)	690 (210)	700 (213)	1324 (404)
Tip Speed, ft/sec (m/sec)	750 (229)	900 (274)	1550 (472)
No. of fan blades	17	23	44

1. For 20,000 lbs (89,000 N) SLS takeoff thrust
2. SL, Std. day, $M_0 = 0.15$

4.4.4 Mechanical Flap Aircraft - The methods used to evaluate the sideline noise characteristics of the MF trade study engine cycles were the same as those used to evaluate the EBF aircraft. Core jet velocities were kept low to reduce jet and core noise and to ensure that the resultant noise levels would be dominated by the fan, which can be suppressed by the use of nacelle acoustic treatment. The takeoff noise levels, on a 500-foot (152 m) sideline, for the M-150-3000 and M-150-4000 aircraft are shown in Tables 4-13 and 4-14. These tables list the component noise levels in terms of PNL, with and without

ACOUSTIC/ENGINE CYCLE TRADEOFFS

EXTERNALLY BLOWN FLAP
150 PASSENGERS
3000 FT (914 m) FIELD LENGTH



PR4-STOL-2394

FIGURE 4-37.

TABLE 4-13

500-FT SIDELINE NOISE COMPARISON

MECHANICAL FLAP 150 PASSENGER
3000 FT (914 M) FIELD LENGTH

100 KNOTS TAKEOFF THRUST

	FPR = 1.32			FPR = 1.45			FPR = 1.57		
NOISE SOURCE	UNTRTD	L/H	TRTD	UNTRTD	L/H	TRTD	UNTRTD	L/H	TRTD
FAN INLET PNL	98.5	0.9	94.0	104.0	0.9	100.0	104.5	0.9	100.0
FAN EXHAUST PNL	105.5	1.6	101.0	107.0	2.6	99.5	107.5	2.7	99.5
TURBINE PNL	92.0	2.4	85.0	92.5	3.8	81.5	93.5	2.6	86.5
CORE PNL	87.5		87.5	89.5		89.5	95.0		95.0
JET PNL	84.5		84.5	90.0		90.0	98.0		98.0
PEAK INLET PNL	99.5		95.0	104.5		100.5	105.0		101.0
PEAK AFT PNL	106.0		101.5	107.5		101.0	108.5		103.0
EPNL	104.0		99.5	105.5		99.0	106.5		101.0

TECHNOLOGY AREA	TECHNOLOGY FACTOR
FAN, TURBINE AND CORE NOISE	−1.5 dB
ACOUSTIC TREATMENT	1.3 x (L/H) 1973
−3.0 dB FOR SHIELDING AND EGA	

PR4-STOL-2392

TABLE 4-14

500-FT SIDELINE NOISE COMPARISON

MECHANICAL FLAP 150 PASSENGER
4000 FT (1219 M) FIELD LENGTH

100 KNOTS TAKEOFF THRUST

NOISE SOURCE	FPR = 132			FPR = 1.45			FPR = 1.57		
	UNTRTD	L/H	TRTD	UNTRTD	L/H	TRTD	UNTRTD	L/H	TRTD
FAN INLET PNL	98.0	0.9	93.5	103.5	0.9	99.5	104.0	0.9	99.5
FAN EXHAUST PNL	105.0	1.6	100.5	106.5	2.6	99.0	107.0	2.7	99.0
TURBINE PNL	91.5	2.4	84.5	92.0	3.8	81.0	93.0	2.6	86.0
CORE PNL	87.0		87.0	89.0		89.0	94.5		94.5
JET PNL	84.0		84.0	89.5		89.5	97.5		97.5
PEAK INLET PNL	99.0		94.5	104.0		100.0	104.5		100.5
PEAK AFT PNL	105.5		101.0	107.0		100.5	108.0		102.5
EPNL	103.5		99.0	105.0		98.5	106.0		100.5

TECHNOLOGY AREA	TECHNOLOGY FACTOR
FAN, TURBINE AND CORE NOISE	−1.5 dB
ACOUSTIC TREATMENT	1.3 x (L/H) 1973
−3.0 dB FOR SHIELDING AND EGA	

PR4-STOL-2390

nacelle acoustic treatment, the resultant peak inlet radiated PNL, peak aft radiated PNL, and estimated peak EPNL on a 500-foot (152 m) sideline. The difference in untreated fan noise levels for the three engine cycles was partially offset by the greater amount of acoustic treatment, as indicated by the treatment (L/H), installed in the higher fan pressure ratio engines. It should be emphasized that the nacelles were not designed for best acoustics as was done in the NASA STOL Systems Study (Reference 1). Minimum drag was the primary criterion with the thrust reverser installation influencing the amount of treatment in the FPR = 1.45 and 1.57 designs.

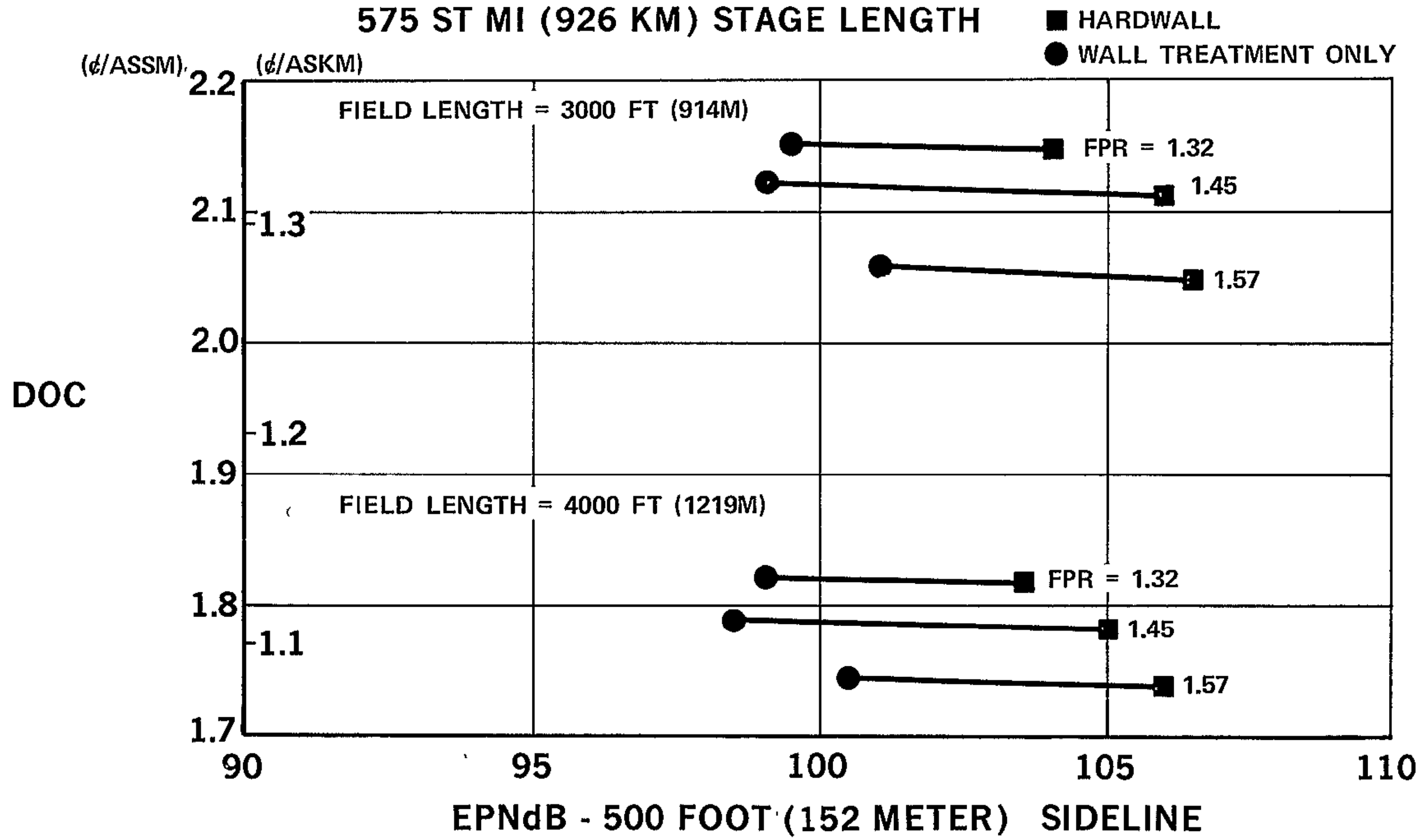
Figure 4-38 is a plot relating EPNdB, on a 500-foot (152 m) sideline, to direct operating cost for the M-150-3000 and M-150-4000 aircraft. The FPR = 1.57 engine cycle was selected for the MF aircraft because of its low direct operating cost relative to the other two engine cycles, and because the sideline noise penalty relative to the other two cycles was minimal for the nacelle acoustic treatment configurations evaluated.

4.5 Summary of Results

For the engine cycles studied, FPR = 1.32, 1.45 and 1.57, several general trends were noted.

The aircraft with 1.57 FPR engines had the highest cruise speed capability and lowest direct operating costs. The DOC advantage of approximately 4 percent compared to the 1.32 FPR engined aircraft is based on a 1972 fuel price of 12 ¢/gallon (31.7 $/m^3). Any significant increase in fuel price will tend to narrow this DOC difference due to the higher fuel consumption of the high FPR engines.

ACOUSTIC/ENGINE CYCLE TRADEOFFS
TWO ENGINE MECHANICAL FLAP
150 PASSENGERS
575 ST MI (926 KM) STAGE LENGTH



PR4-STOL-2602

FIGURE 4-38.

Sideline noise levels were slightly higher for the aircraft with the highest FPR engines. With the incorporation of nacelle acoustic linings, the 1.57 FPR engined aircraft are only 2 EPNdB noisier than the aircraft with the quietest engine studied. There were essentially no weight or DOC penalties associated with the use of nacelle wall acoustic treatment provided overall nacelle dimensions were not increased.

The 4000-foot (1219 m) field length aircraft are 0.5 EPNdB quieter in terms of sideline noise than those with 3000-foot (914 m) field lengths. This is due to the smaller engine thrust size and higher takeoff speeds of the 4000-foot (1219 m) field length airplanes. The higher takeoff speeds reduce the time duration factor used in EPNdB calculations. In addition, the DOC for the 3000-foot (914 m) aircraft was 18 percent higher than the 4000-foot (1219 m) aircraft and the mission fuel 24 percent greater.

From these results, the twin-engine 4000-foot (1219 m) mechanical-flap aircraft with 1.57 FPR engines was selected to evaluate operational techniques for noise reduction along with the E-150-3000 aircraft.

and the E-150-3000 aircraft with 10 percent oversized engines which was derived in Section 3.3.

The general arrangement of the final design E-150-3000 aircraft is shown in a three-view drawing, Figure 5-1. The aircraft with oversized engines is essentially identical except for small changes in wing and tail surface areas and engine size.

Figure 3-8 is a sizing plot for the two EBF aircraft and a characteristics summary is shown in Table 5-2.

The engine for these EBF aircraft is the Allison PD287-3 with a takeoff bypass ratio of 17.5 and a variable-pitch fan with a pressure ratio of 1.25. Table 5-1 gives basic information on the engine. The uninstalled performance and weight are from Reference 1. The installation and installed performance are included in Appendix B, and are the same as used in the study reported in Reference 1.

The engine parameters used for acoustic calculations are shown in Figures 5-2 through 5-4. The mass flows of Figure 5-2 are for a 20,000-pound (89,000 N) reference-size engine and were linearly scaled to the required sizes.

TABLE 5-1

ENGINE FOR EBF AIRCRAFT

Engine Type	PD287-3 Variable-Pitch Fan
Fan Pressure	1.25
Bypass Ratio	17.5
Overall Pressure Ratio	20
Fan Tip Speed	750 ft/sec (229 m/sec)
Exhaust Configuration	Separate flow Variable-area fan exhaust Fixed-area primary exhaust

5.0 OPERATIONAL TECHNIQUES FOR NOISE REDUCTION

5.1 Introduction

This section evaluates the potential and applicability of using take-off and landing operational techniques to reduce the community noise impact caused by the operation of aircraft from selected airports. The aircraft used for this evaluation were the M-150-4000 aircraft with 1.57 FPR engines from the propulsion system and acoustic trade study and the final design E-150-3000 aircraft from the NASA STOL Systems Study (Reference 1). Also, a version of the EBF aircraft with oversized engines was evaluated at one of the airports.

The number of people highly annoyed within the single-event 80 EPNdB contour was used as the noise impact criteria. This required an assumption of the fraction of people impacted that are highly annoyed for noise levels greater than 80 EPNdB. This assumption will be defined and discussed later in this section. The evaluation started with a parametric analysis of operational techniques based on a uniform population distribution. From the parametric analysis, a low-impact operational procedure was selected for each aircraft, which resulted in the least number of people highly annoyed. The low-impact procedure was then evaluated at four airports where a minimum-impact procedure was developed at each airport by tailoring the operational techniques to minimize the noise impact.

5.2 EBF Aircraft Characteristics

Two externally-blown-flap aircraft were used in the study of operational noise-reduction techniques; the final design 150-passenger, 3000-foot (914 m) field length aircraft from the NASA Short-Haul System Study (Reference 1)

TABLE 5-2

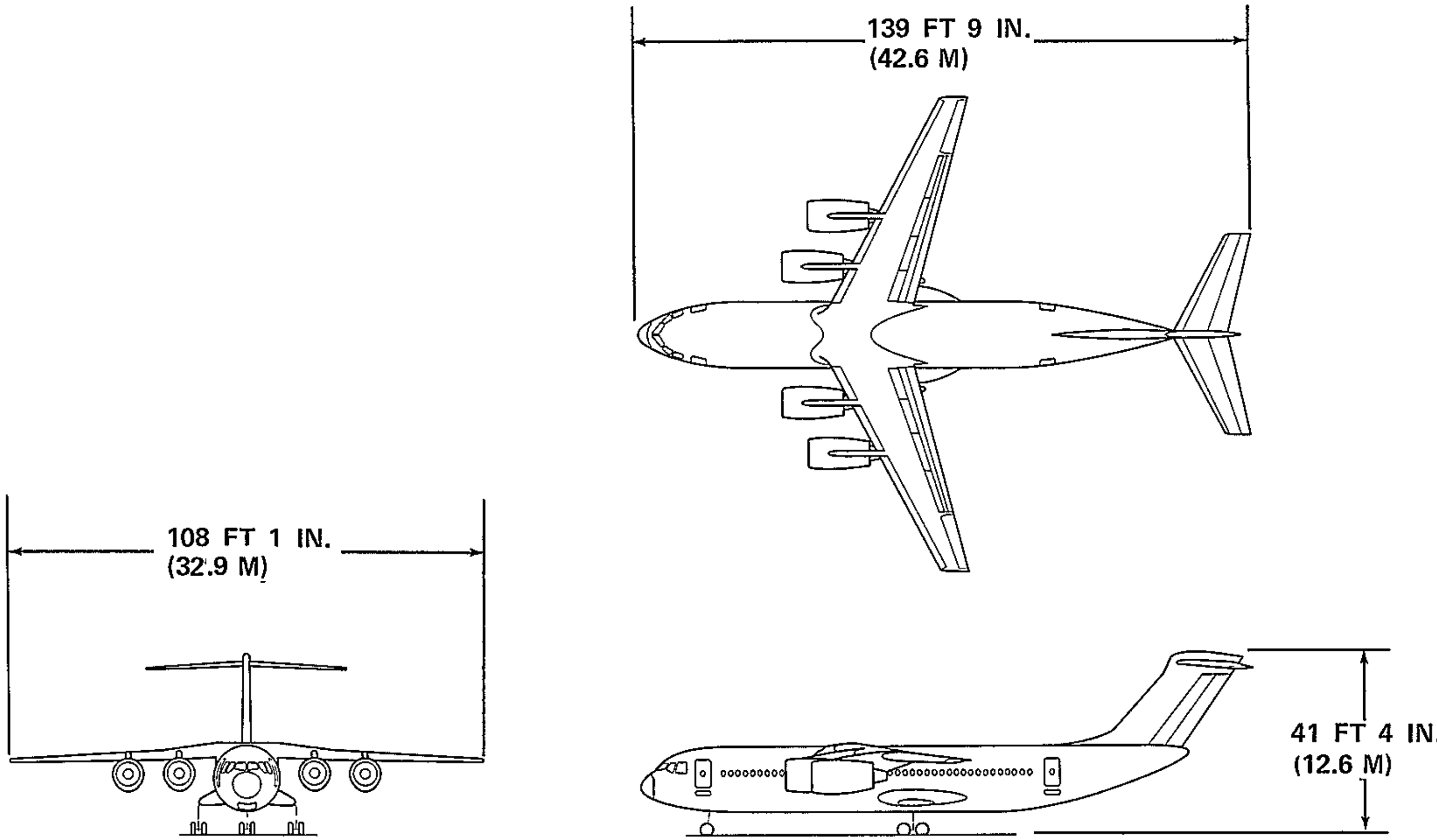
EBF AIRCRAFT SELECTED FOR VARIATION OF

OPERATIONAL TECHNIQUES FOR NOISE REDUCTION

PD287-3 ENGINES (1.25 FPR)

		FINAL DESIGN AIRCRAFT	10% OVER-SIZED
Payload	Passengers	150	150
Field Length	ft. (M)	3,000 (914)	3,000 (914)
Takeoff Gross Weight	lb. (kg)	149,000 (67,600)	151,200 (68,600)
Wing Area	ft.^{2} (M^2)	1,461 (135.7)	1,400 (130.1)
Thrust per Engine	lb. (N)	18,260 (81,220)	20,040 (89,140)
W/S	lb/ft.^{2} (kg/M^2)	102 (498)	108 (527)
T/W		0.490	0.530
OEW	lb. (kg)	102,610 (46,540)	103,900 (47,130)
M_{cr} @ 26,000 ft. (7,925M)		0.69	0.71
D.O.C. @ 575 ST. MI. (926 KM)	¢/ASSM (¢/ASKM)	2.075 (1.289)	2.082 (1.293)
EPNL @ 500 ft. Sideline (152M)	EPNdB	97.1	96.9

EXTERNALLY BLOWN FLAP AIRCRAFT



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PR3-STOL-1512C

FIGURE 5-1.

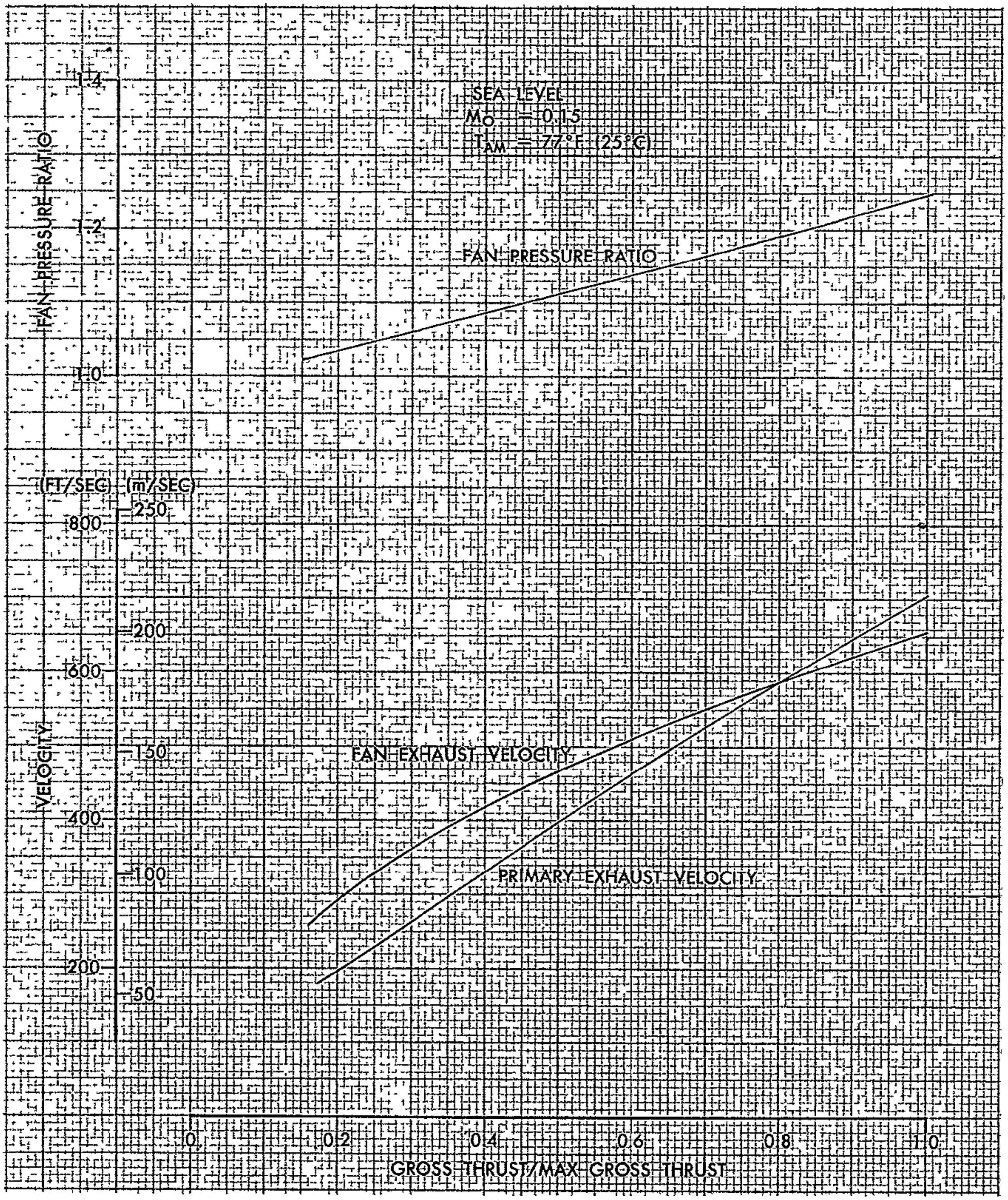

FIGURE 5-3. EXHAUST VELOCITIES AND FAN PRESSURE RATIO

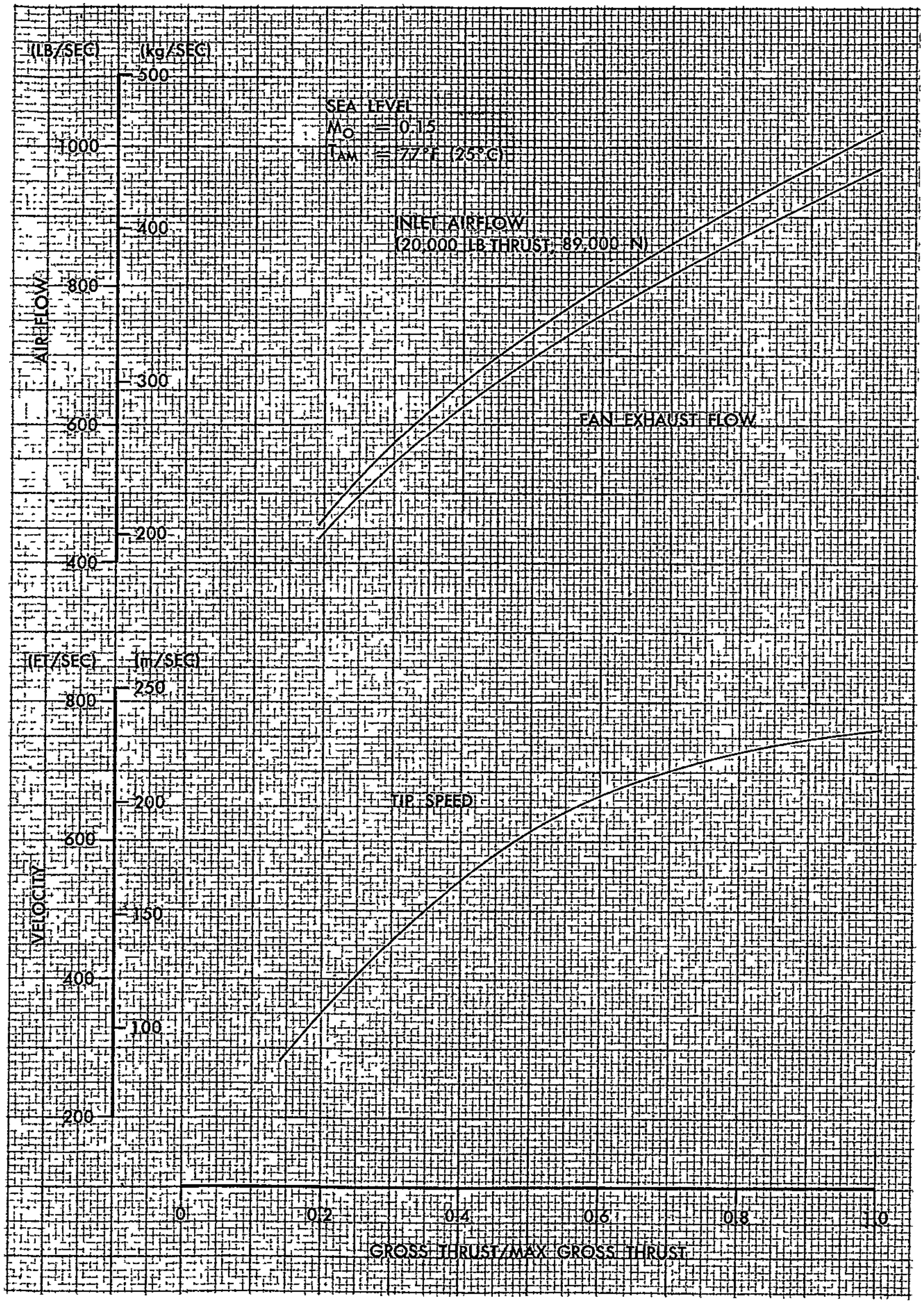

FIGURE 5-2. TIP SPEED AND AIRFLOWS—ENGINES FOR EBF AIRCRAFT

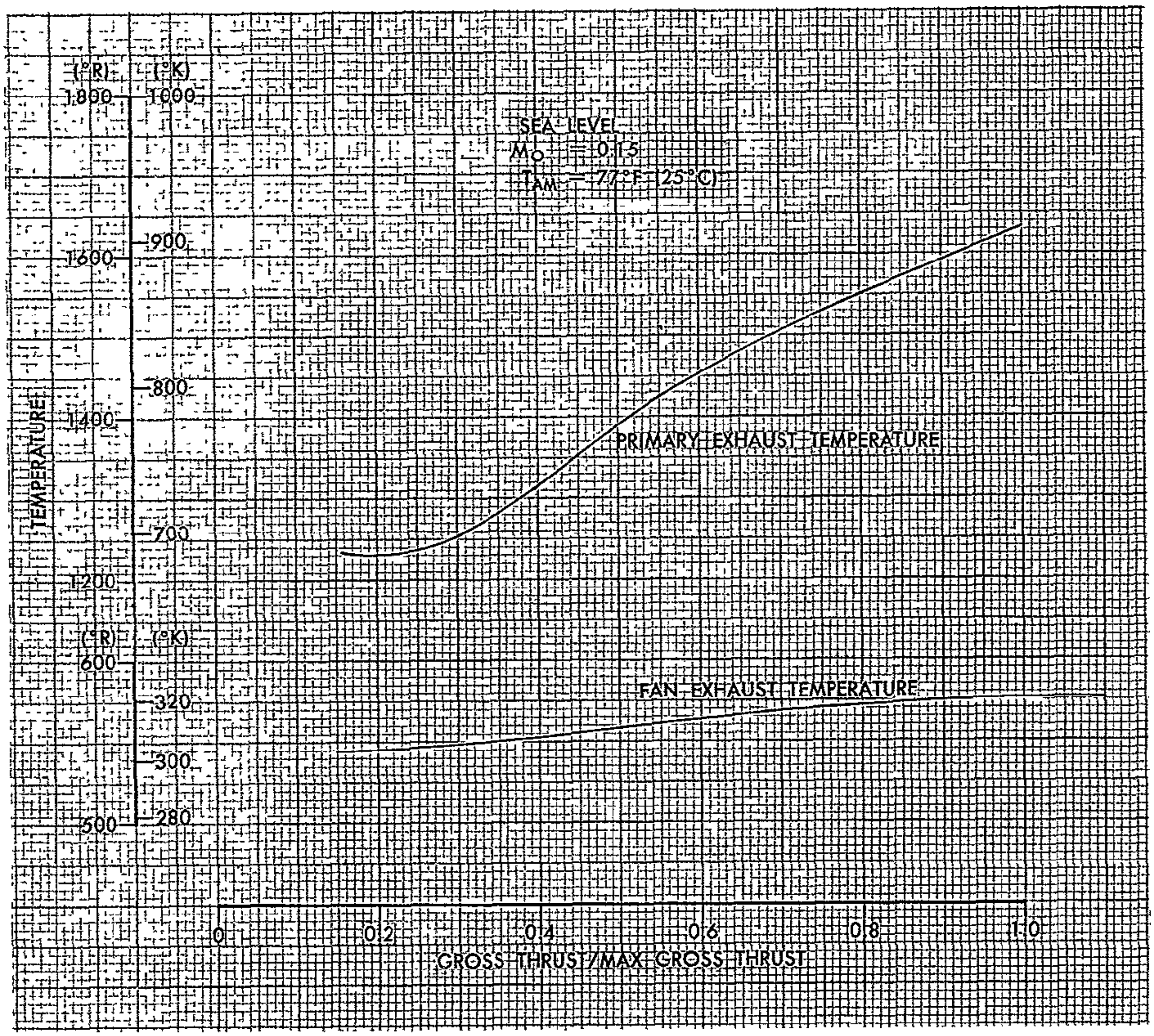

FIGURE 5-4. EXHAUST TEMPERATURES FOR EBF AIRCRAFT

5.3 MF Aircraft Characteristics

The selection of the mechanical-flap STOL aircraft for the operational noise reduction techniques study was based on the results of the acoustic trade study (see Section 4.0). In this study, the 1.57 FPR engine with acoustic wall treatment was found to produce the lowest direct operating costs and sideline noise levels only 2 EPNdB higher than the quietest engine examined. This engine has a fixed-pitch fan and a bypass ratio of 5.9. Engine installation and performance are discussed in Section 4.0 and Table 5-3 lists the major engine characteristics. The engine parameters used for acoustic calculations are shown in Figures 5-5 and 5-6. The mass flows shown are for a 20,000-pound (89,000 N) reference-thrust size engine and were scaled linearly to the engine size used on the aircraft.

Initially both the M-150-3000 and M-150-4000 aircraft with two 1.57 FPR engines were selected for examination. Standard flight profiles and noise contours were calculated for both aircraft as described in Section 5.4. Based on these contours, there was no appreciable difference in community noise impact (using a uniform population distribution) for the two aircraft. Selection of the 4000-foot (1219 M) field length aircraft for study at the specific airports was made on the basis of its lower DOC, 1.74 ¢/ASSM (1.08 ¢/ASKM) as compared to 2.06 ¢/ASSM (1.28 ¢/ASKM) for the 3000-foot (914 M) field length aircraft, and its lower mission fuel consumption.

Sizing plots for the M-150-3000 and M-150-4000 aircraft are shown in Figures 5-7 and 5-8 respectively. Both aircraft were sized for minimum DOC which occurs at the W/S and T/W where landing and takeoff are equally critical. A brief summary comparing the characteristics of the two aircraft

is presented in Table 5-4 and three-view drawings are shown in Figures 5-9 and 5-10. Note that the sizing criterion leads to a higher T/W for the longer field length due to the higher W/S for the M-150-4000 aircraft. The resulting increase in climb gradient capability for this aircraft contributes to its smaller noise contour areas as will be shown later in this chapter.

TABLE 5-3

ENGINE FOR MF AIRCRAFT

Engine Type	Fixed-Pitch Fan
Fan Pressure	1.57
Bypass Ratio	5.9
Overall Pressure Ratio	22.7
Fan Tip Speed	1550 ft/sec (472 m/sec)
Exhaust Configuration	Separate flow Fixed-area fan exhaust Fixed-area primary exhaust

5.4 Aircraft Acoustics Characteristics

5.4.1 <u>Evaluation Procedures</u> - The evaluation of operational techniques for noise reduction was performed on the basis of aircraft noise contours and community noise impact. Contours of 100, 95, 90, 85, and 80 EPNdB were generated using the Douglas-developed Aircraft Noise Contour/Community Noise Impact Evaluation (A1FA) digital computer program in conjunction with a Gerber plotter. A1FA inputs required for noise contours include noise data, in the form of EPNL as a function of slant distance, and flight path and performance data such as the aircraft position, airspeed, flap setting, and engine

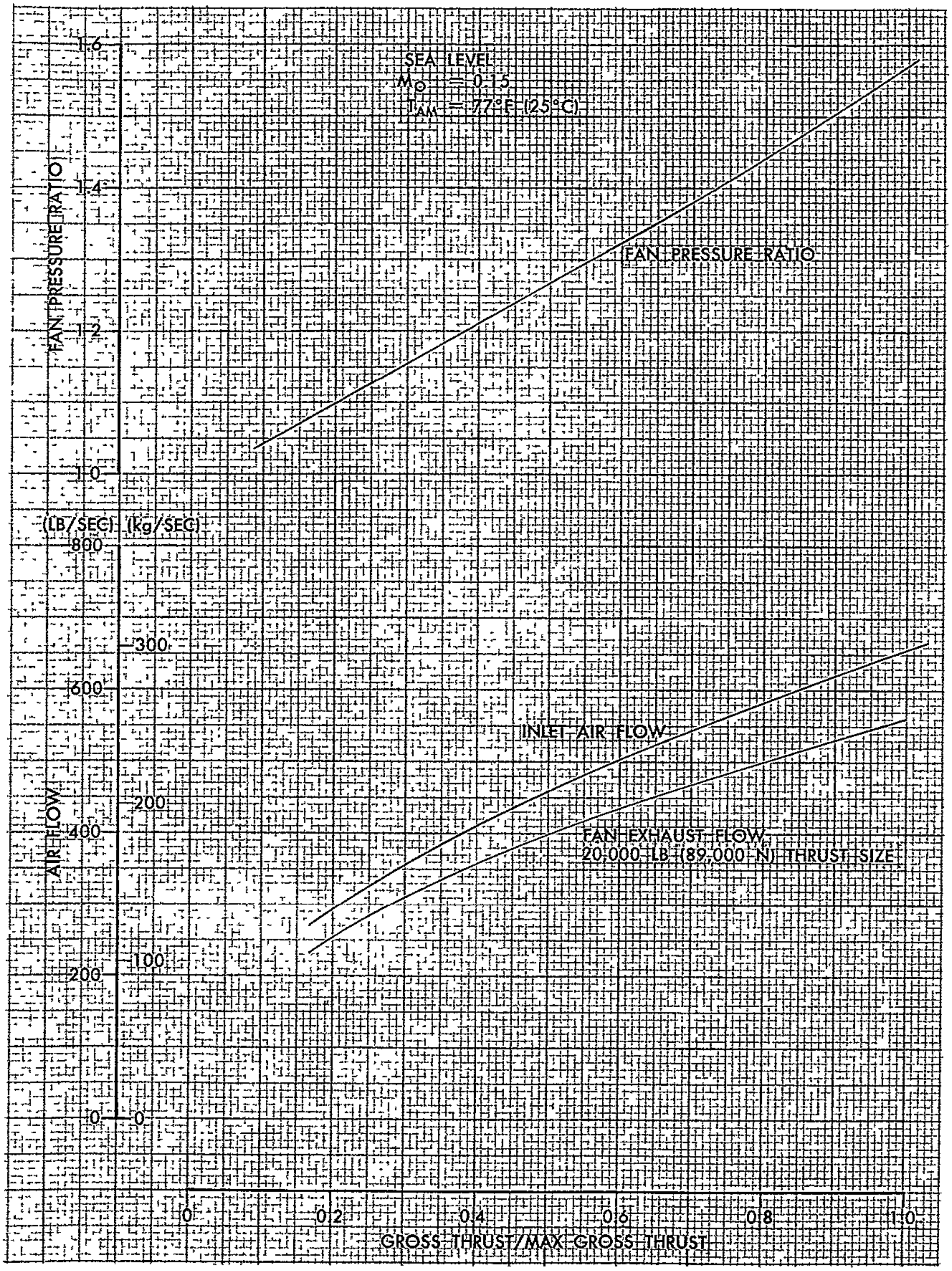

FIGURE 5-5. AIR FLOWS AND FAN PRESSURE RATIO

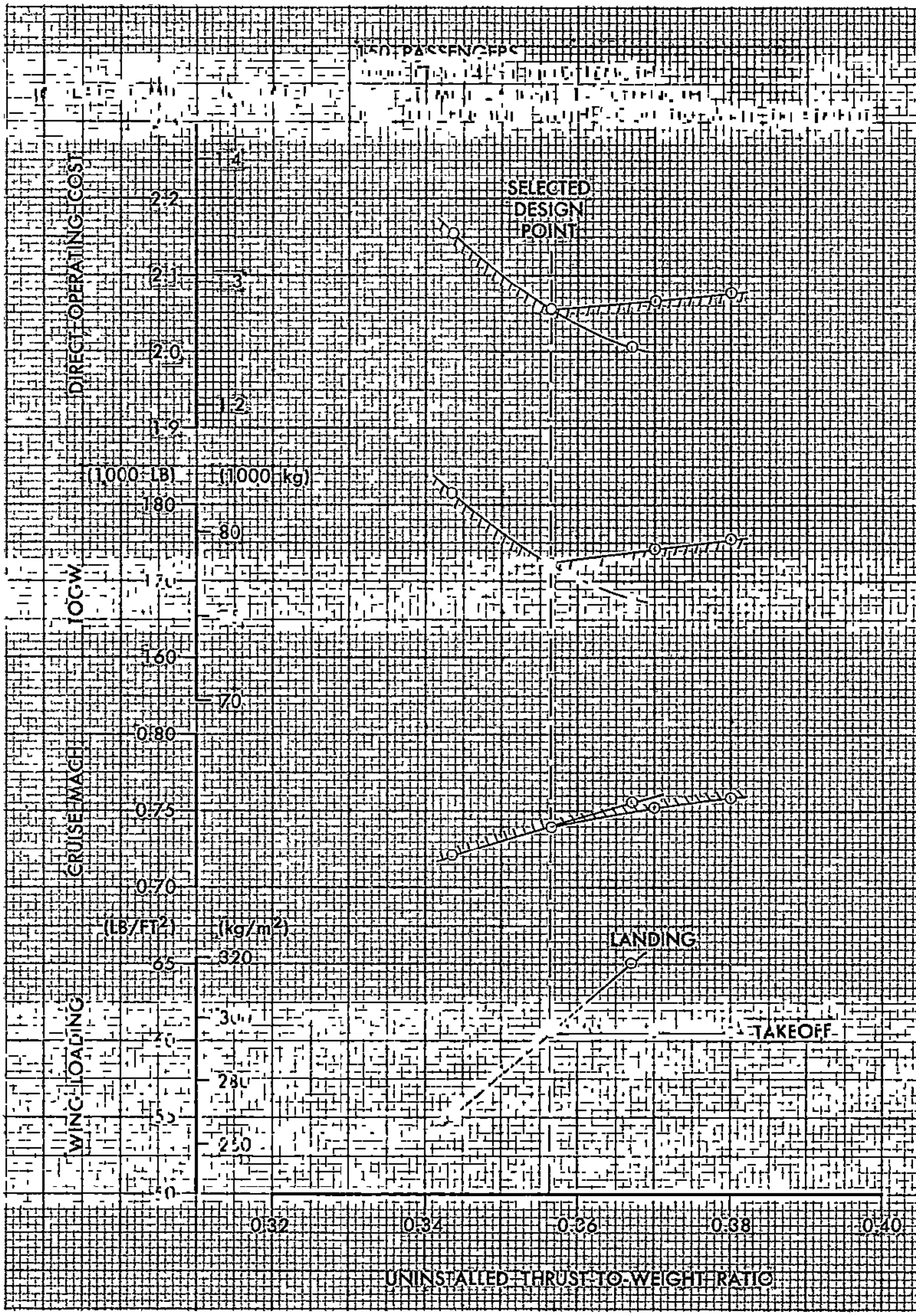

FIGURE 5-7. AIRCRAFT SIZING – M-150-3000

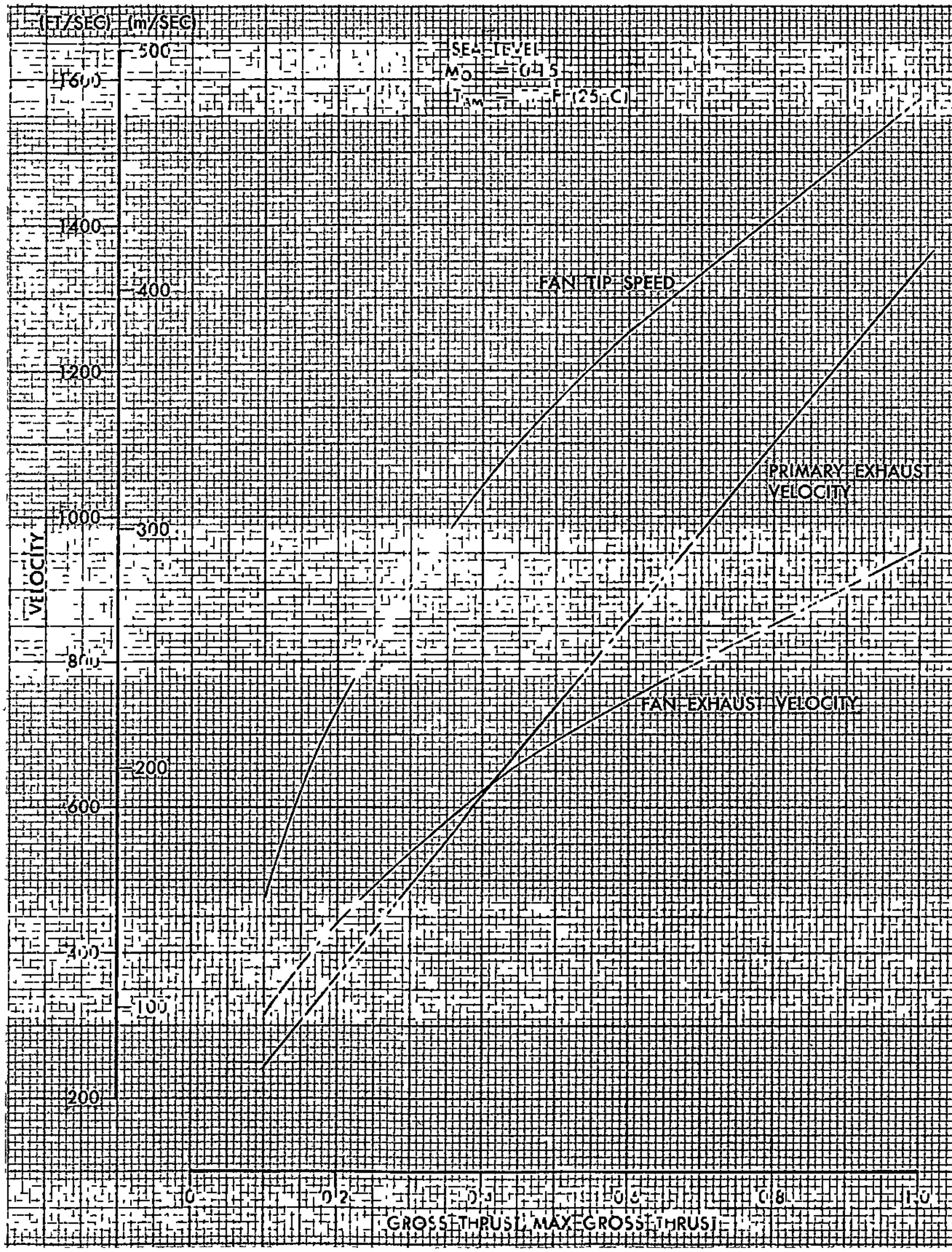

FIGURE 5-6. EXHAUST VELOCITIES AND FAN TIP SPEED FOR MECHANICAL FLAP AIRCRAFT

FIGURE 5-8. AIRCRAFT SIZING — M-150-4000

TABLE 5-4

CANDIDATE MECHANICAL FLAP AIRCRAFT

OPERATIONAL TECHNIQUES FOR NOISE REDUCTION

1.57 FPR ENGINES WITH ACOUSTIC WALL TREATMENT

			SELECTED AIRCRAFT
Payload	Passengers	150	150
Field Length	ft. (M)	3,000 (914)	4,000 (1,219)
Takeoff Gross Weight	lb. (kg)	172,300 (78,150)	143,600 (65,140)
Wing Area	$ft.^2$ (M^2)	2,848 (264.6)	1,679 (156.0)
Thrust per Engine	lb. (N)	30,680 (136,470)	26,870 (119,520)
W/S	lb/ft^2 (kg/M^2)	60.5 (295.4)	85.5 (417.4)
T/W		0.356	0.374
OEW	lb. (kg)	122,940 (55,770)	97,550 (44,250)
M_{cr} @ 30,000 ft. (9144 M)		0.74	0.77
D.O.C. @ 575 ST. MI. (926 KM)	¢/ASSM (¢/ASKM)	1.86 (1.16)	1.58 (0.98)
EPNL @ 500 ft. Sideline	EPNdB	101.0	100.5

GENERAL ARRANGEMENT

M-150-3000 — TWO 5.9/1.57 ENGINES

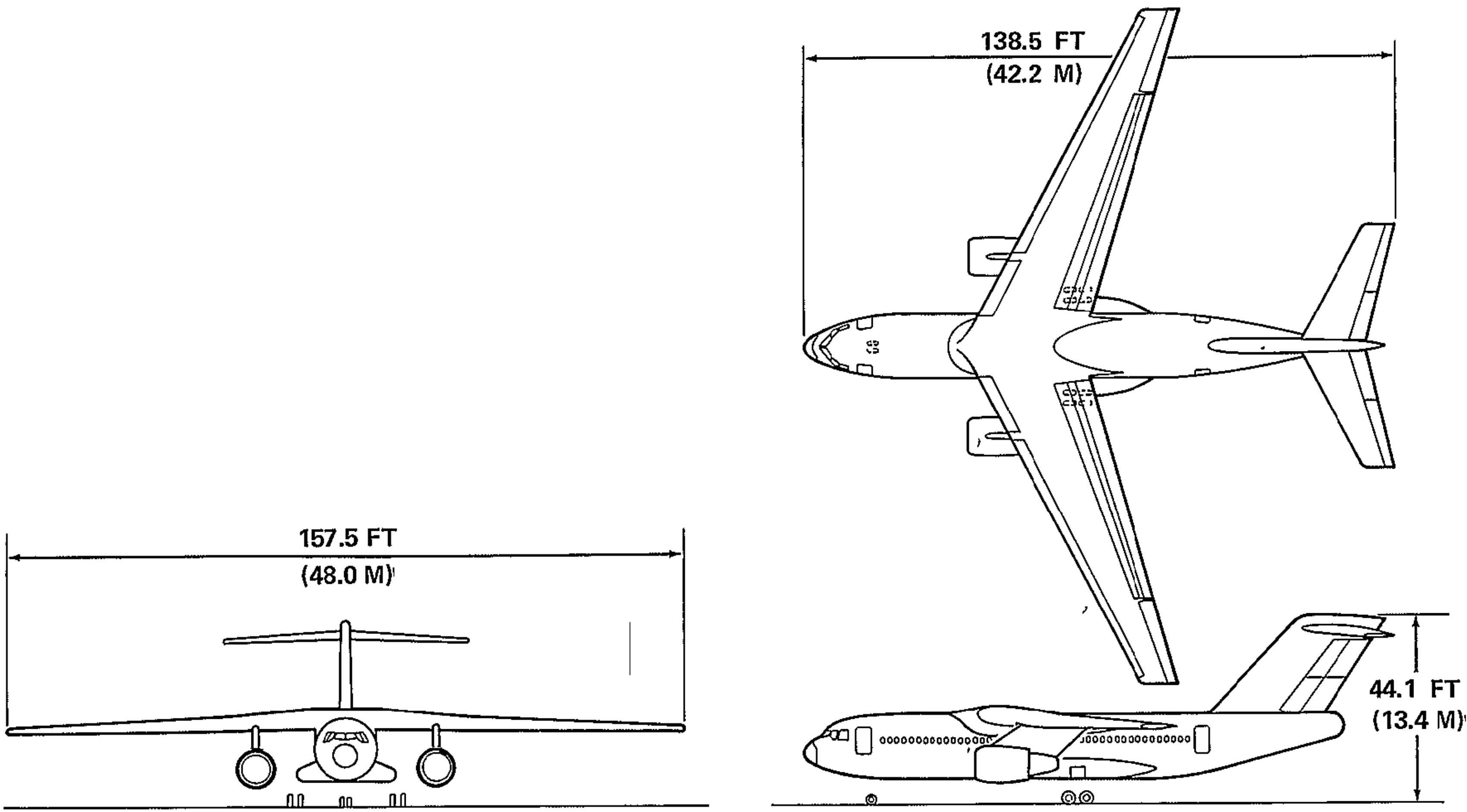

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FIGURE 5-9.

GENERAL ARRANGEMENT

M-150-4000 — TWO 5.9/1.57 ENGINES

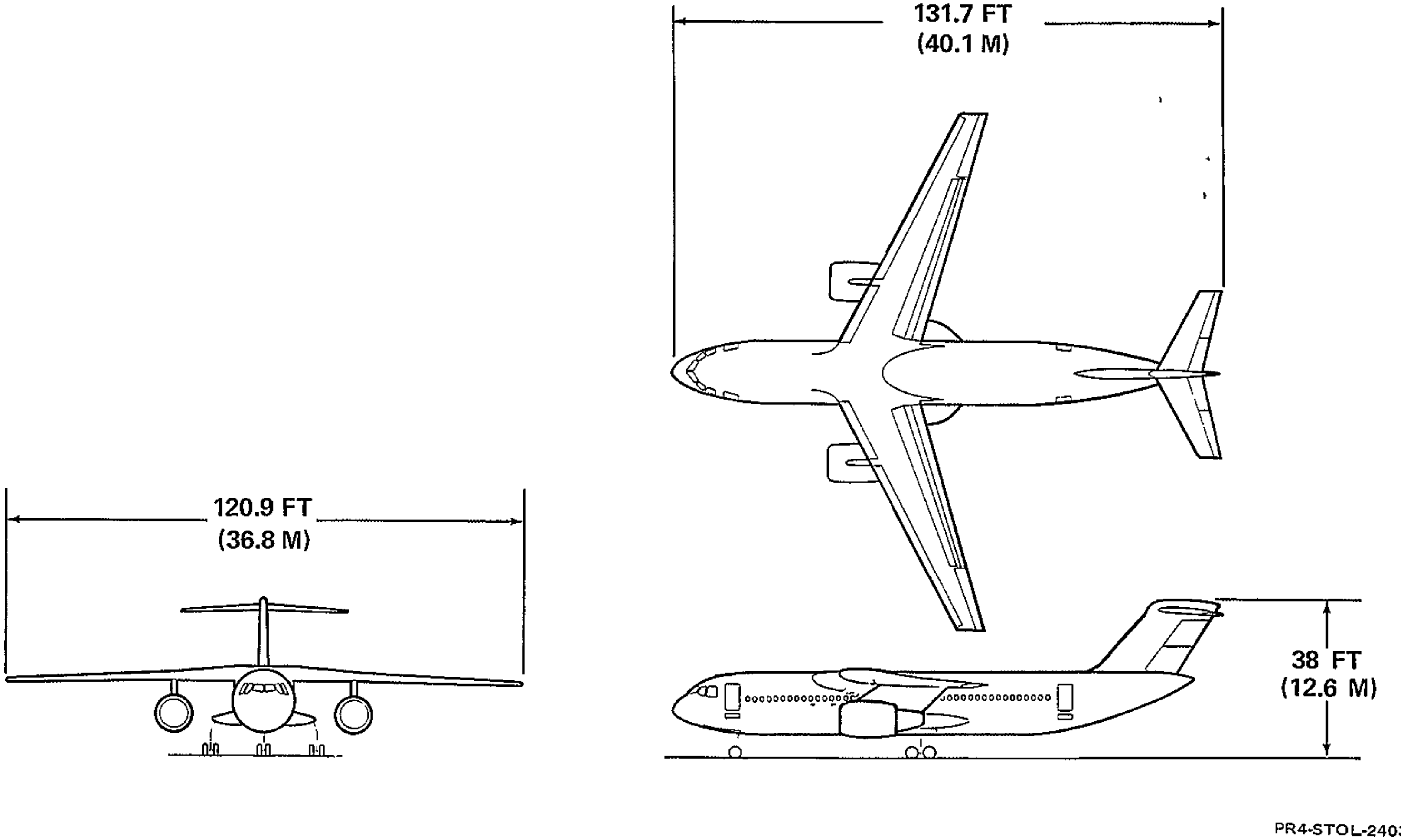


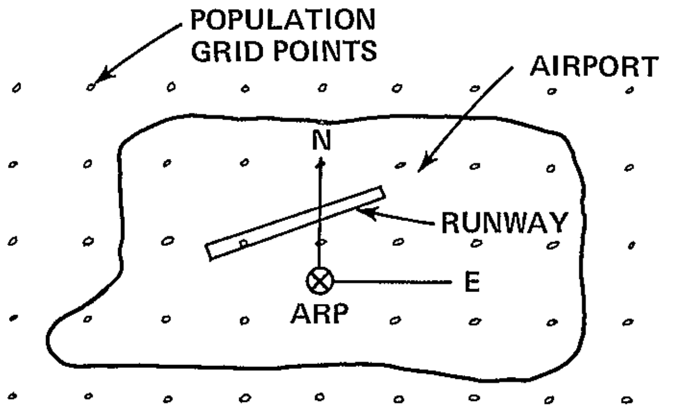
FIGURE 5-10.

operating parameters.

Using this program, the aircraft noise level, in terms of EPNL, corresponding to a takeoff and approach flight path was calculated at each 500-foot (152 m) sideline interval, relative to the airport runway centerline, to form a rectangular grid of EPNL values. Contours of equal EPNL were calculated by interpolation within the grid. The EPNL at each grid point was determined by finding the minimum distance to the flight path and relating the noise level to the aircraft operating conditions at that point on the flight path. EPNL adjustments were made for airspeed, based on a 10 log (ratio of the actual airspeed to the reference airspeed) relationship, and ground attenuation (EGA) and fuselage shielding based on SAE ARP 1114.

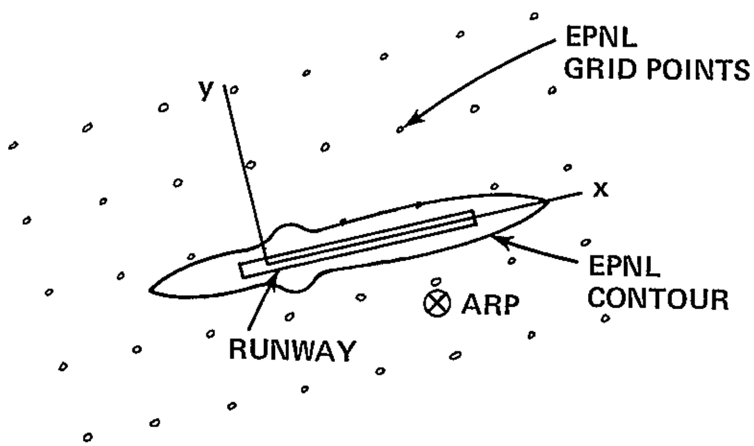
The evaluation of community noise impact required additional information in the form of population density data at each airport. The population density data was formulated as the average number of people at each 500-foot (152 m) sideline interval relative to a rectangular coordinate system which had its origin at the airport reference point. The community noise impact was calculated by a transformation of the EPNL coordinate system into the population density coordinate system, interpolation to determine the EPNL at each population (P) grid point, calculating the fraction (K) of people highly annoyed, and calculating the sum of the product of K and P for all grid points within the 80 EPNdB contour. The methodology of this procedure is shown in Figure 5-11A. A sample output of the AlFA computer program is shown in Appendix C-2. The relationship of the fraction of people highly annoyed to EPNL, defined in Reference 2 and shown in Figure 5-11B, assumes zero annoyance for a noise level below or equal to 80 EPNdB. For noise levels greater than 80 EPNdB the relationship is linear and passes through 40 percent highly

COMMUNITY NOISE IMPACT EVALUATION



POPULATION REFERENCE COORDINATE SYSTEM

ORIGIN: AIRPORT REFERENCE POINT
AXES: N, S, E, W
POPULATION AT 500-FOOT INTERVALS



NOISE CONTOUR COORDINATE SYSTEM

ORIGIN: BRAKE RELEASE POINT
AXES: RELATIVE TO THE CHOSEN RUNWAY
EPNL AT 500-FOOT INTERVALS

- TRANSFORM THE EPNL GRID TO THE POPULATION REFERENCE COORDINATE SYSTEM AND INTERPOLATE TO FIND THE EPNL AT EACH POPULATION GRID POINT WITHIN THE 80 EPNdB CONTOUR

- CALCULATE AN ANNOYANCE FACTOR (K) AT EACH GRID POINT (FRACTION OF PEOPLE HIGHLY ANNOYED)

$$K = 0.02\ (\text{EPNdB} - 80) \qquad \text{EPNdB} > 80$$
$$K = 0 \quad \text{EPNdB} \leq 80$$

REFERENCE: D.O.T. TM72-1, 6-6-72

- CALCULATE THE COMMUNITY NOISE IMPACT (NUMBER OF PEOPLE HIGHLY ANNOYED)

$$\text{IMPACT} = \sum_{i=1}^{N} K_i \times P_i$$

K_i = ANNOYANCE FACTOR OF THE iTH GRID POINT

P_i = POPULATION DENSITY OF THE iTH GRID POINT

N = TOTAL NUMBER OF GRID POINTS WITHIN THE 80 EPNdB CONTOUR

PR3-STOL-2062B

FIGURE 5-11A.

COMMUNITY RESPONSE TO AIRCRAFT NOISE

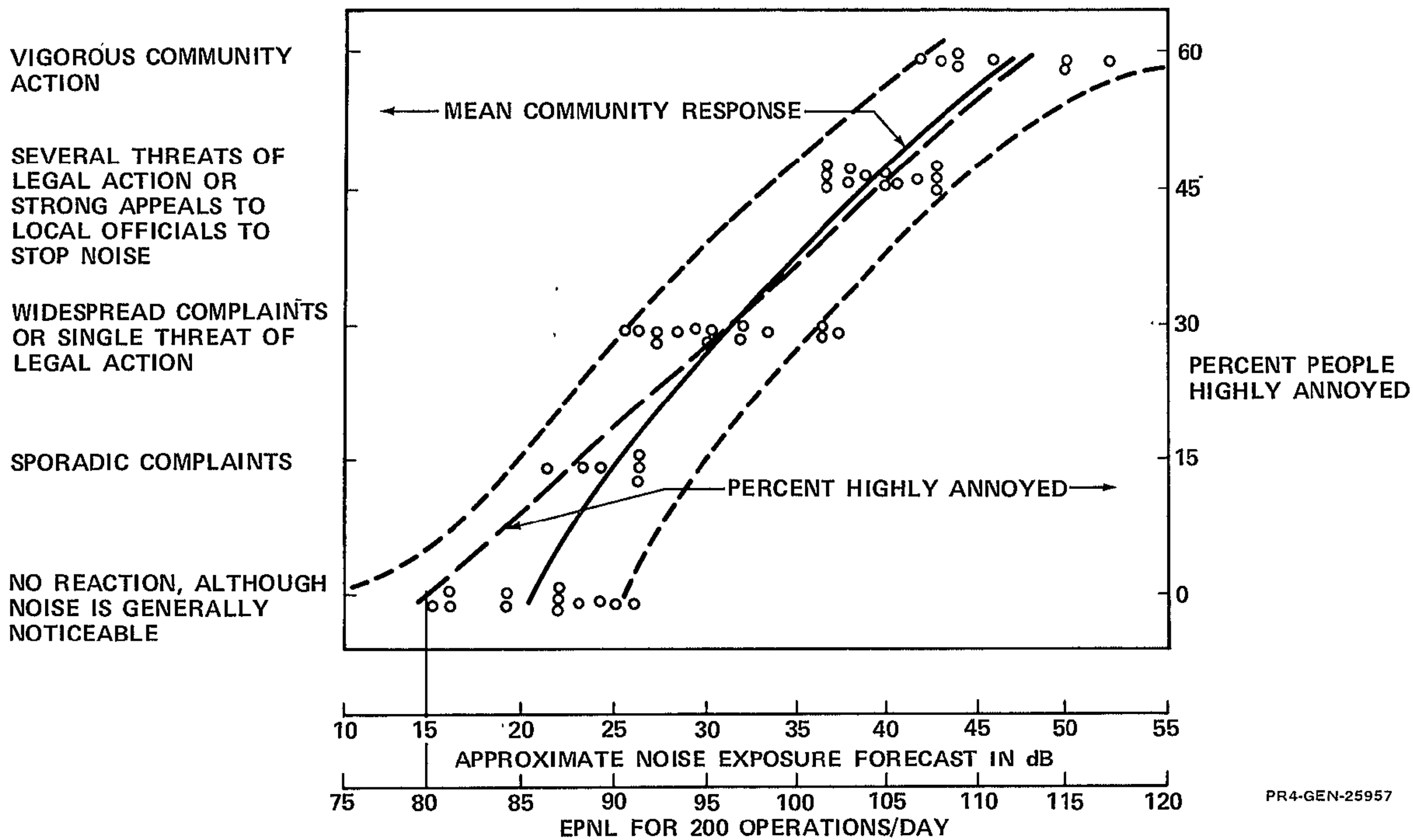


FIGURE 5-11B.

annoyed at 100 EPNdB. Although it is believed that the function relating the fraction of people highly annoyed to the EPNL is meaningful, it is recognized that this function will differ depending upon the type of community surrounding the airport and the time of day. The procedure used for the single-event EPNL levels herein also can be applied to composite noise prediction methodologies, such as the Noise Exposure Forecast (NEF).

5.4.2 EPNL vs Distance Plots - Plots of EPNL as a function of slant distance were calculated in accordance with the procedures discussed in Appendix C-1. The plots are shown in Figures 5-12 and 5-13 for the M-150-3000 and M-150-4000 aircraft, and Figures 5-14 and 5-15 for the E-150-3000 aircraft. Two figures are shown for the E-150-3000 aircraft because the engine noise and propulsive-lift system noise were calculated independently and then summed to arrive at the total aircraft noise. Figure 5-14 is the EPNL map for the E-150-3000 engine noise only, and Figure 5-15 is an EPNL map of the E-150-3000 powered-lift system noise for typical takeoff and landing operating conditions.

5.4.3 Standard Flight Profiles - Standard takeoff and landing procedures were defined as a starting point for the parametric study of operational techniques for noise reduction. The parametric variations in this study are based on perturbations from these standard flight procedures. It was desired that the standard flight procedures be representative of normal commercial operations.

Takeoff - The standard takeoff flight profiles for the E-150-3000 aircraft and E-150-3000 with 10 percent oversized engines are shown in Figures 5-16A and 5-16B. Similar profile plots for the M-150-3000 and M-150-4000 aircraft are shown in Figures 5-17 and 5-18.

EPNL vs DISTANCE

MECHANICAL FLAP 150 PASSENGERS 3000 FT (914 m) FIELD LENGTH

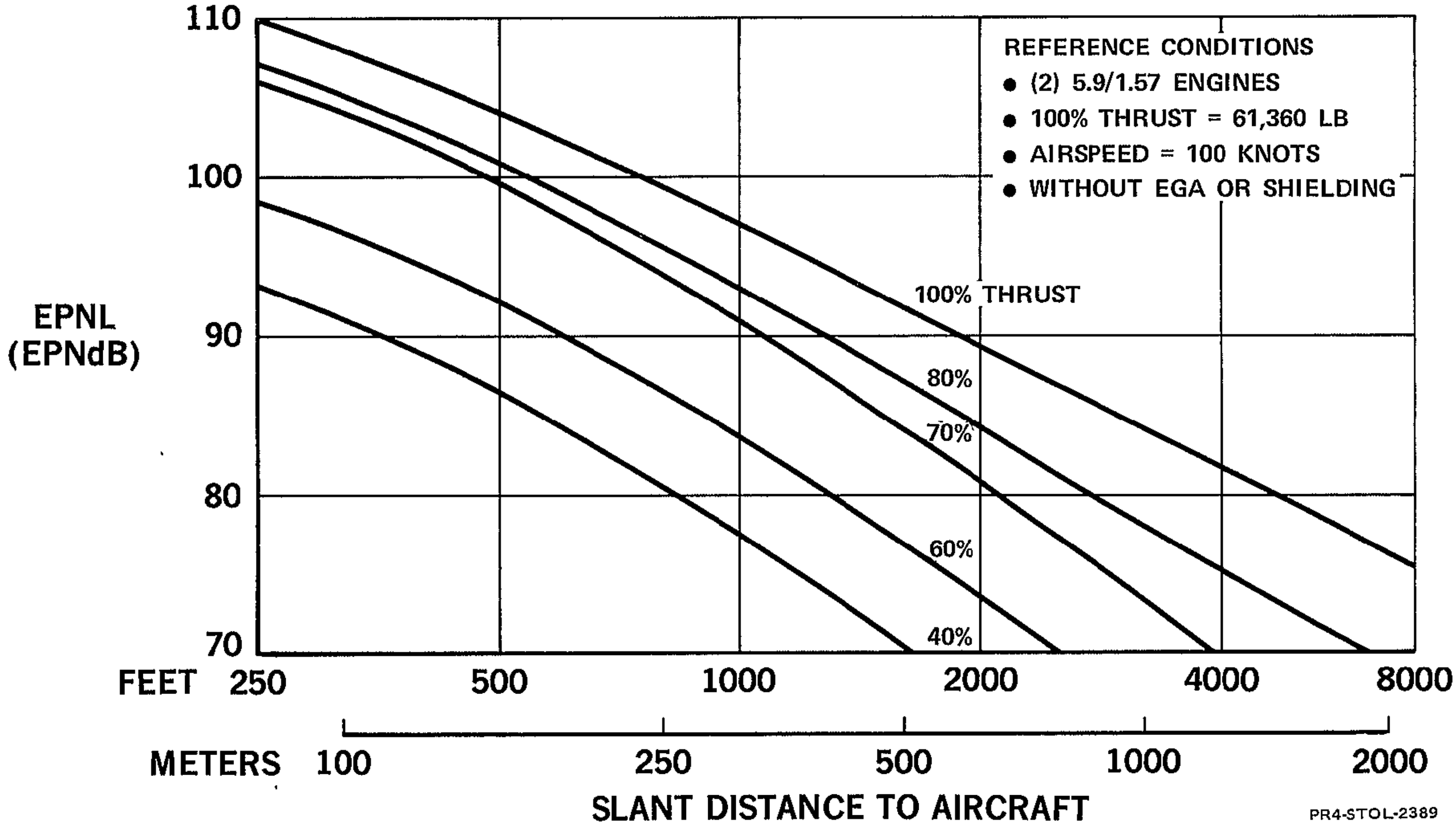


FIGURE 5-12.

EPNL vs DISTANCE

MECHANICAL FLAP 150 PASSENGERS 4000 FT (1219 m) FIELD LENGTH

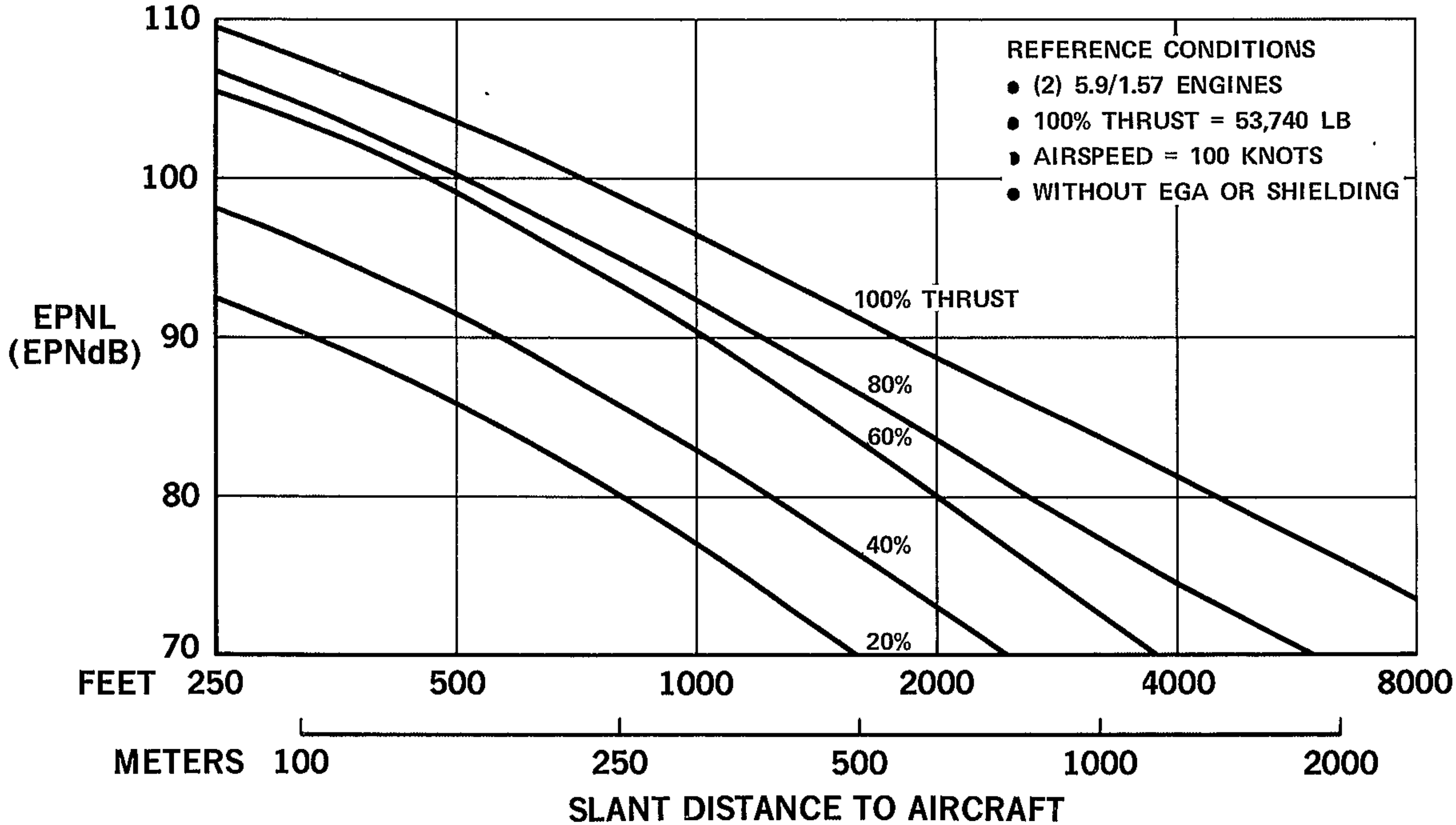


FIGURE 5-13.

ENGINE EPNL vs DISTANCE

EXTERNALLY BLOWN FLAP 150 PASSENGERS 3000 FT (914 m) FIELD LENGTH

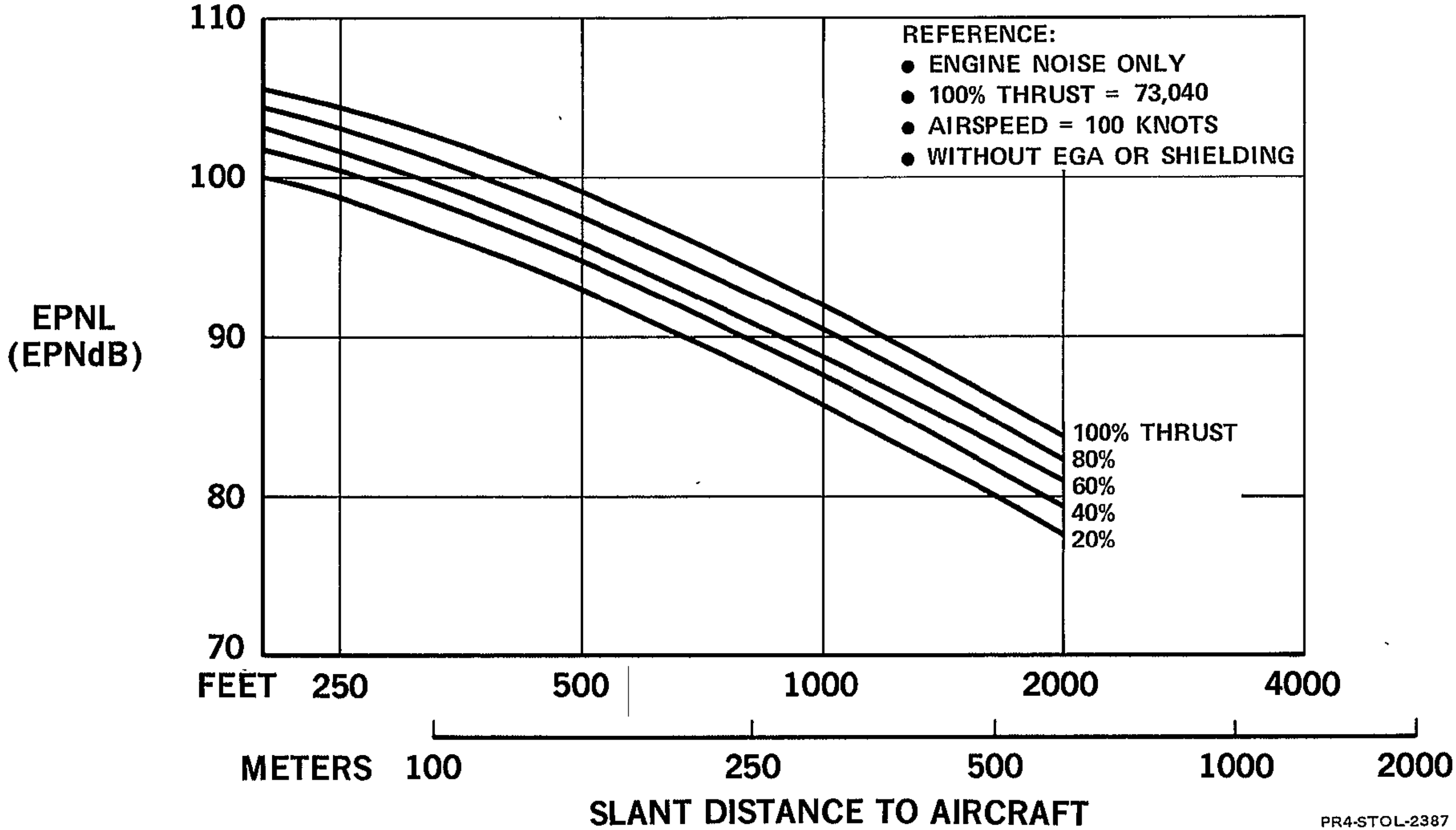


FIGURE 5-14.

PLS EPNL vs DISTANCE

EXTERNALLY BLOWN FLAP 150 PASSENGERS 3000 FT (914 m) FIELD LENGTH

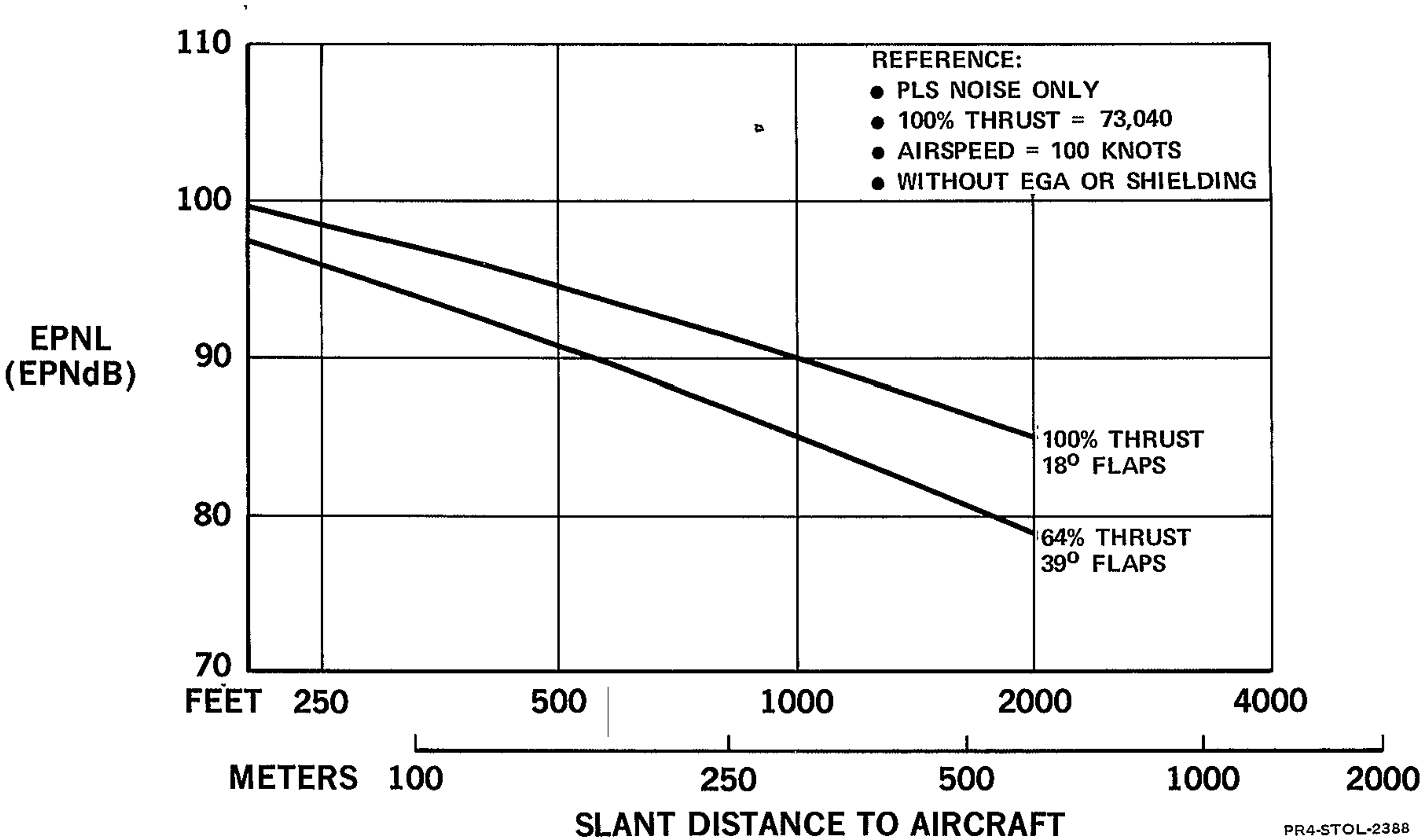


FIGURE 5-15.

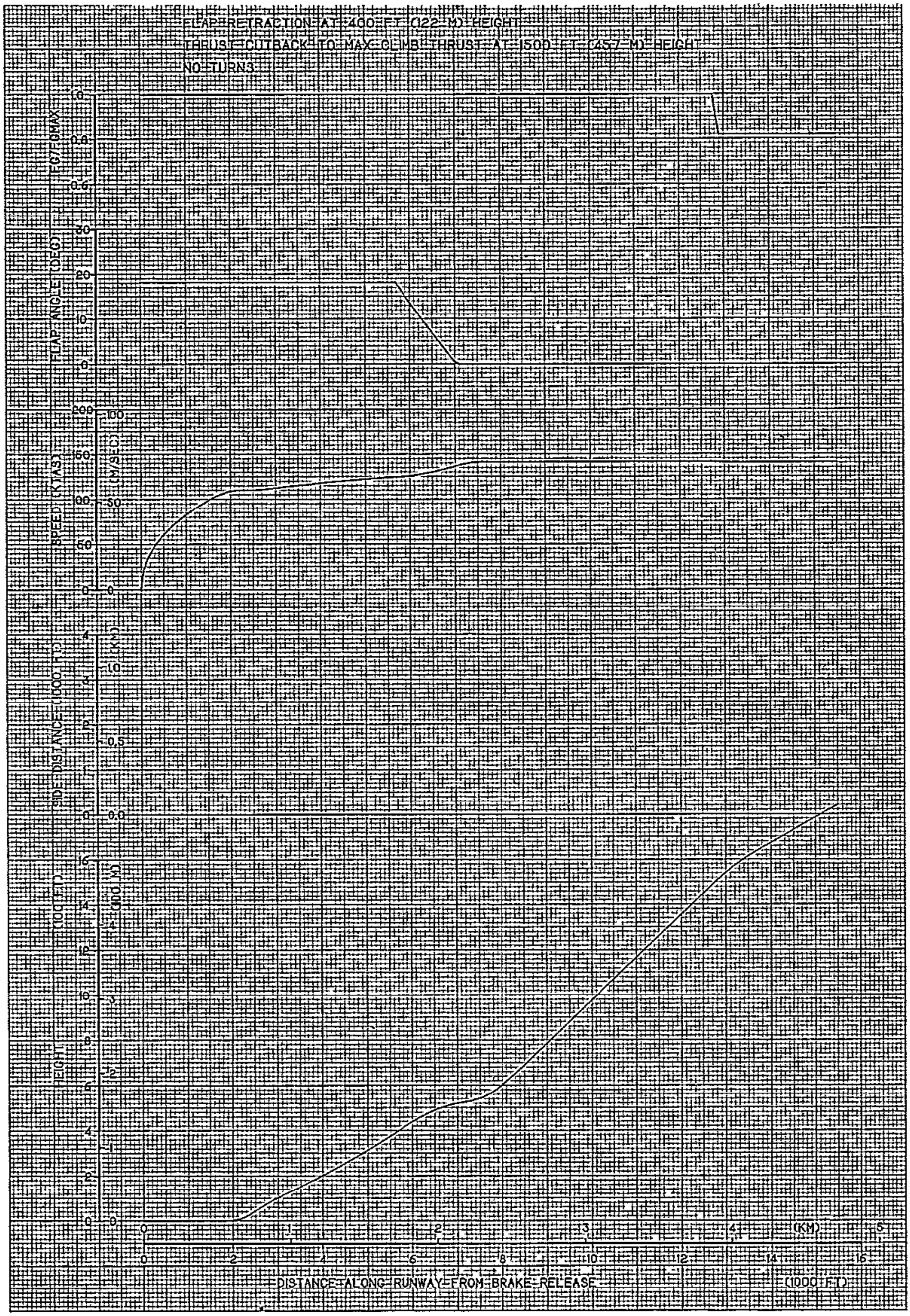


FIGURE 5-16A STANDARD TAKEOFF PROFILE E-150-3000 AIRCRAFT

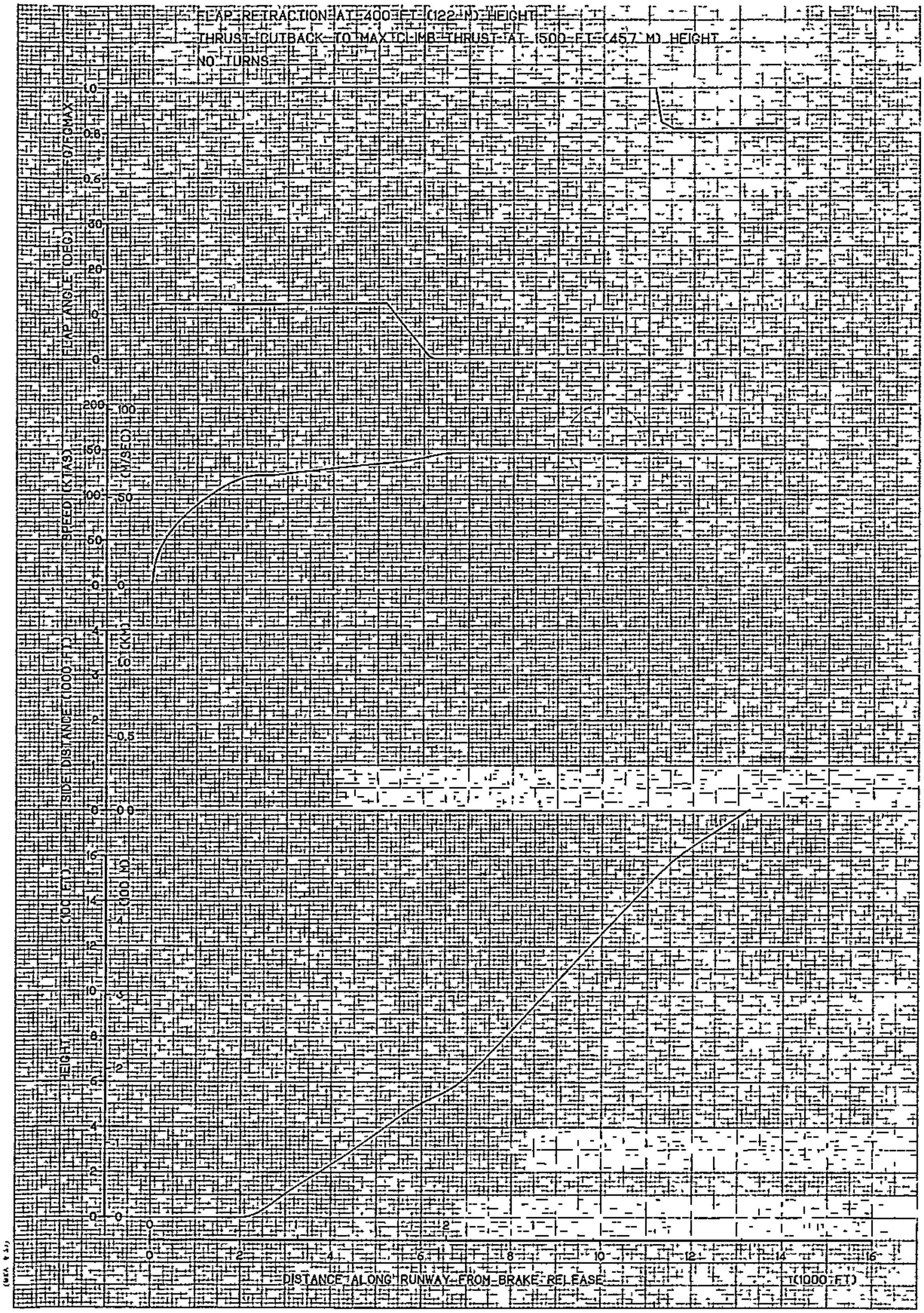


FIGURE 5-16B STANDARD TAKEOFF PROFILE OVERSIZED E-150-3000 AIRCRAFT

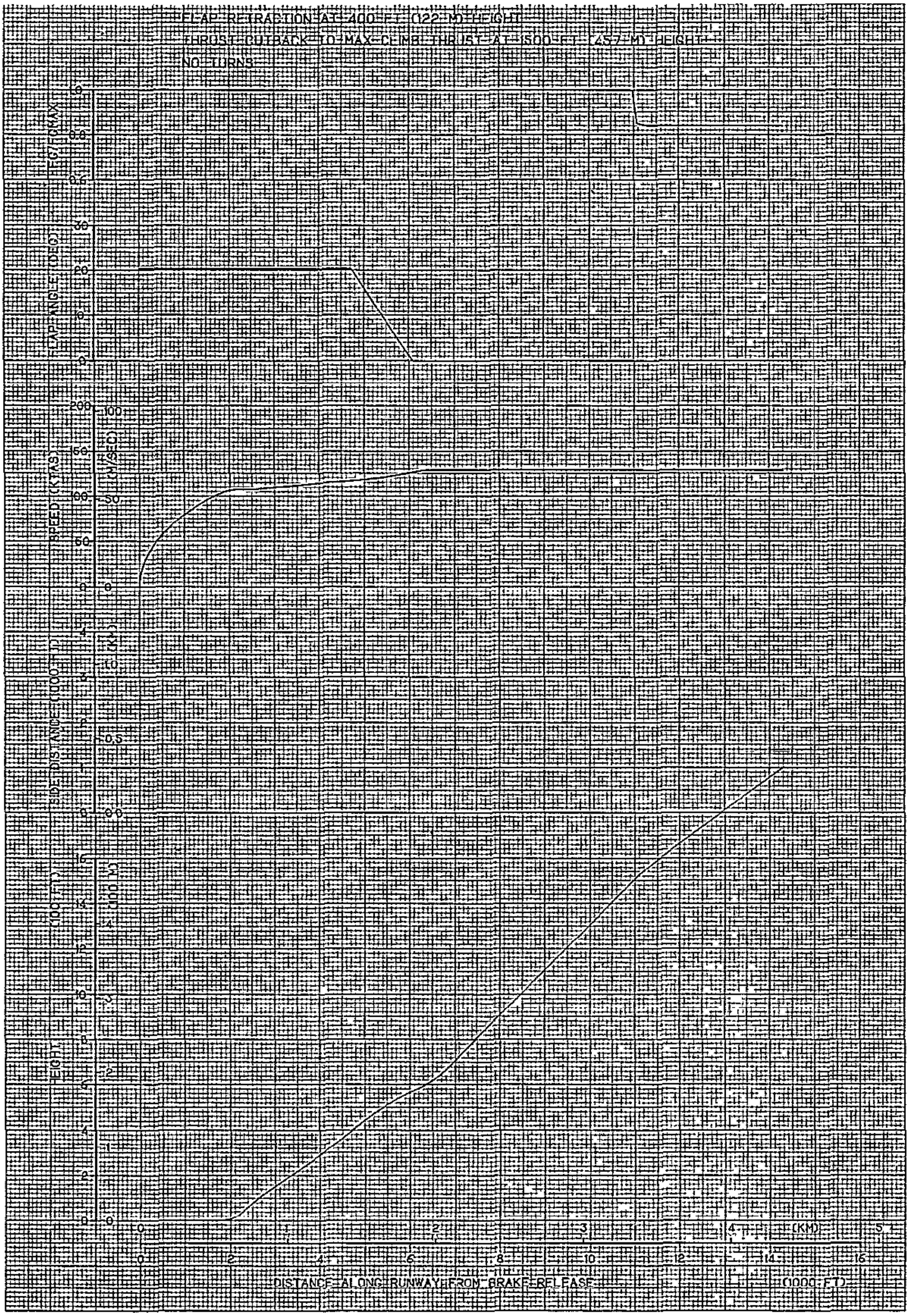


FIGURE 5-17 STANDARD TAKEOFF FLIGHT PROFILE M-150-3000 AIRCRAFT

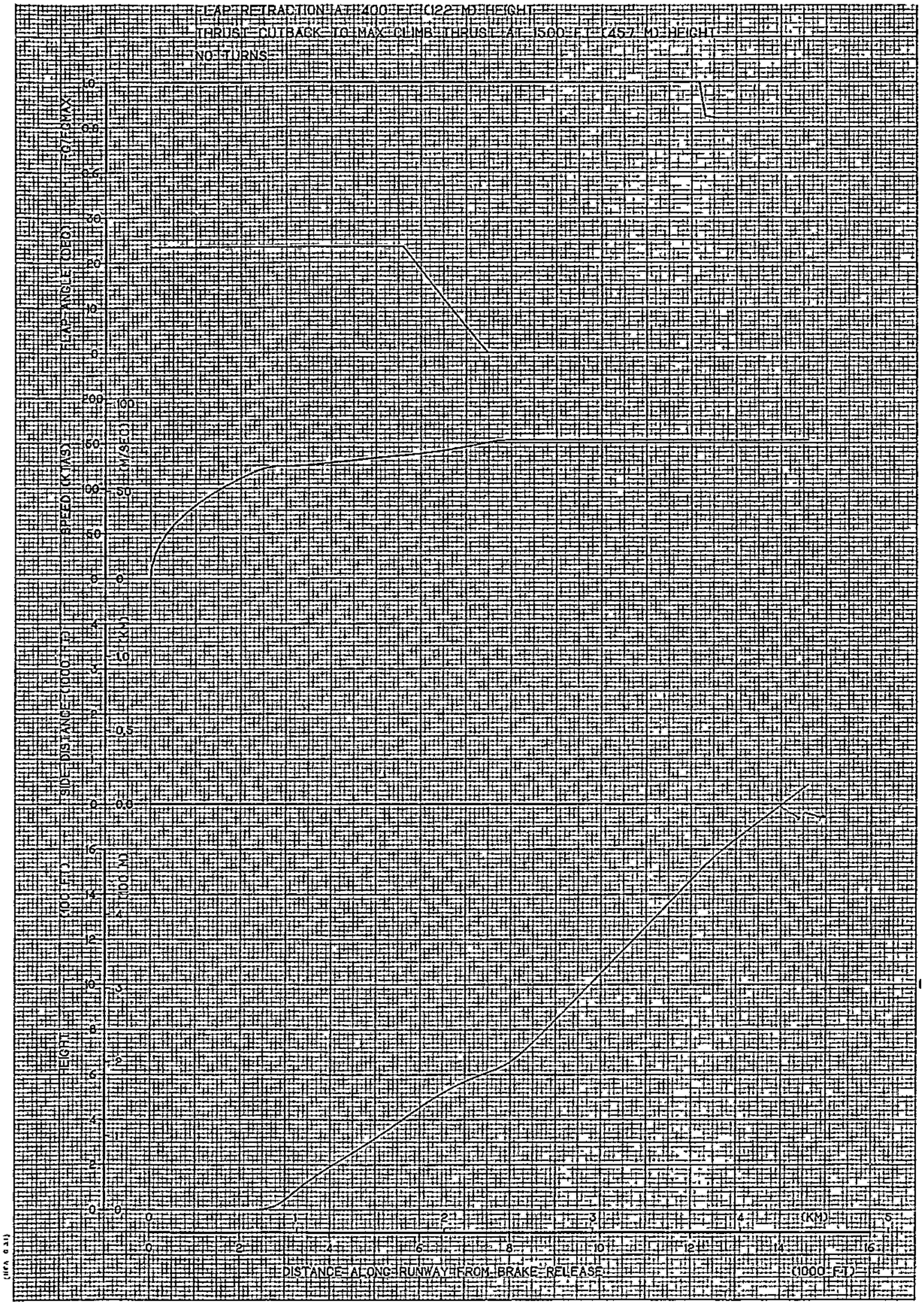


FIGURE 5-18 STANDARD TAKEOFF FLIGHT PROFILE M-150-4000 AIRCRAFT

The standard climbout maneuver consists of the following segments:

1. Takeoff - Normal STOL takeoff; gear retraction assumed to be complete 10 seconds after liftoff; SL, 77^{o}F (25^{o}C) ambient conditions.

2. Accelerate - Accelerate to V_{CLIMB} while maintaining constant aircraft attitude (θ); θ selected such that V_{CLIMB} is reached by the time flap retraction is complete; V_{CLIMB} selected for maximum climb gradient with the aircraft in the zero-flap, slats-extended configuration provided this speed is greater than 1.3 times the one engine failed stall speed. Figure 5-19 illustrates selection of V_{CLIMB} for the final design E-150-3000 aircraft. In this case the stall speed criterion dictates V_{CLIMB} rather than maximum flight path angle.

3. Flap Retraction - Retract flaps from takeoff position to zero flap at a rate of 3 degrees per second (0.05 rad/sec) commencing at 400 feet (122 m). Slats are left extended during the climb to provide high maneuver margins.

4. Climb - Climb at constant speed to a height of 1500 feet (457 m).

5. Thrust Cutback - Starting at 1500 feet (457 m), reduce thrust at a rate of 30 percent per second from takeoff thrust to climb thrust.

6. Climb at constant speed with climb thrust.

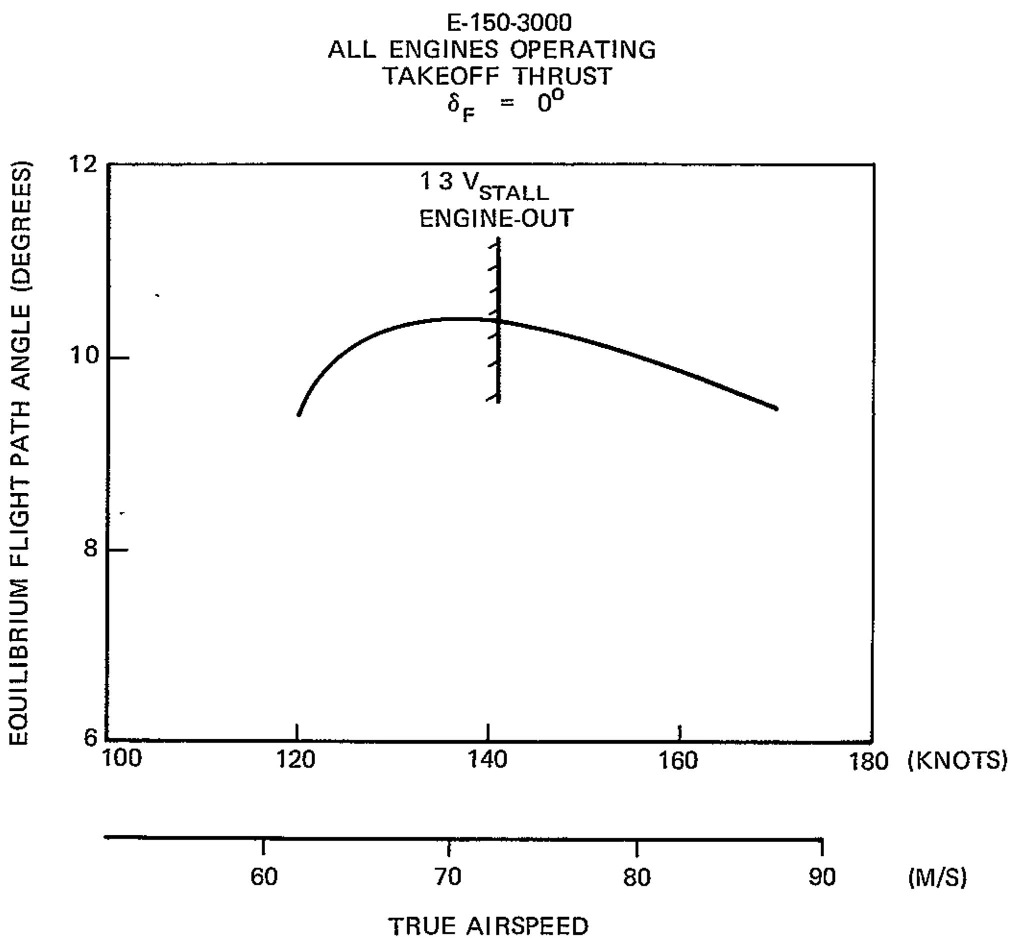


FIGURE 5-19 CLIMB SPEED SELECTION

Landing - Standard approach flight profiles for the E-150-3000 and E-150-3000 with 10 percent oversized engines are shown in Figures 5-20 and 5-21 and for the M-150-3000 and M-150-4000 aircraft in Figures 5-22 and 5-23. The standard approach flight procedure is a decelerating approach with a constant glide slope. Glide slope angle was selected to provide a sink rate of 900 fpm (4.6 m/sec) at the threshold height with final approach speed. This results in path angles of approximately 5.4 degrees (0.094 rad) for a 3000-foot (914 m) field length aircraft and 4.5 degrees (0.079 rad) for a 4000-foot (1219 m) field length aircraft. Approach flap is used down to a height of 1000 feet (305 m) at which point flaps are extended at a rate of 3 degrees per second (0.05 rad/sec) to the landing flap setting. As the threshold is approached, thrust is increased as required to maintain the glide slope and to stabilize approach speed.

5.4.4 Standard Noise Contours - Based on the standard takeoff and approach flight paths defined in Section 5.4.3, standard noise contours of 100, 95, 90, 85 and 80 EPNdB were generated for the M-150-3000, M-150-4000, and E-150-3000 aircraft. These noise contours are shown in Figures 5-24 to 5-26. In each case, the size of the takeoff contours is much larger than the size of the landing contours. This would seem to imply that, for these aircraft, takeoff operational techniques would offer the most potential for reducing community noise impact.

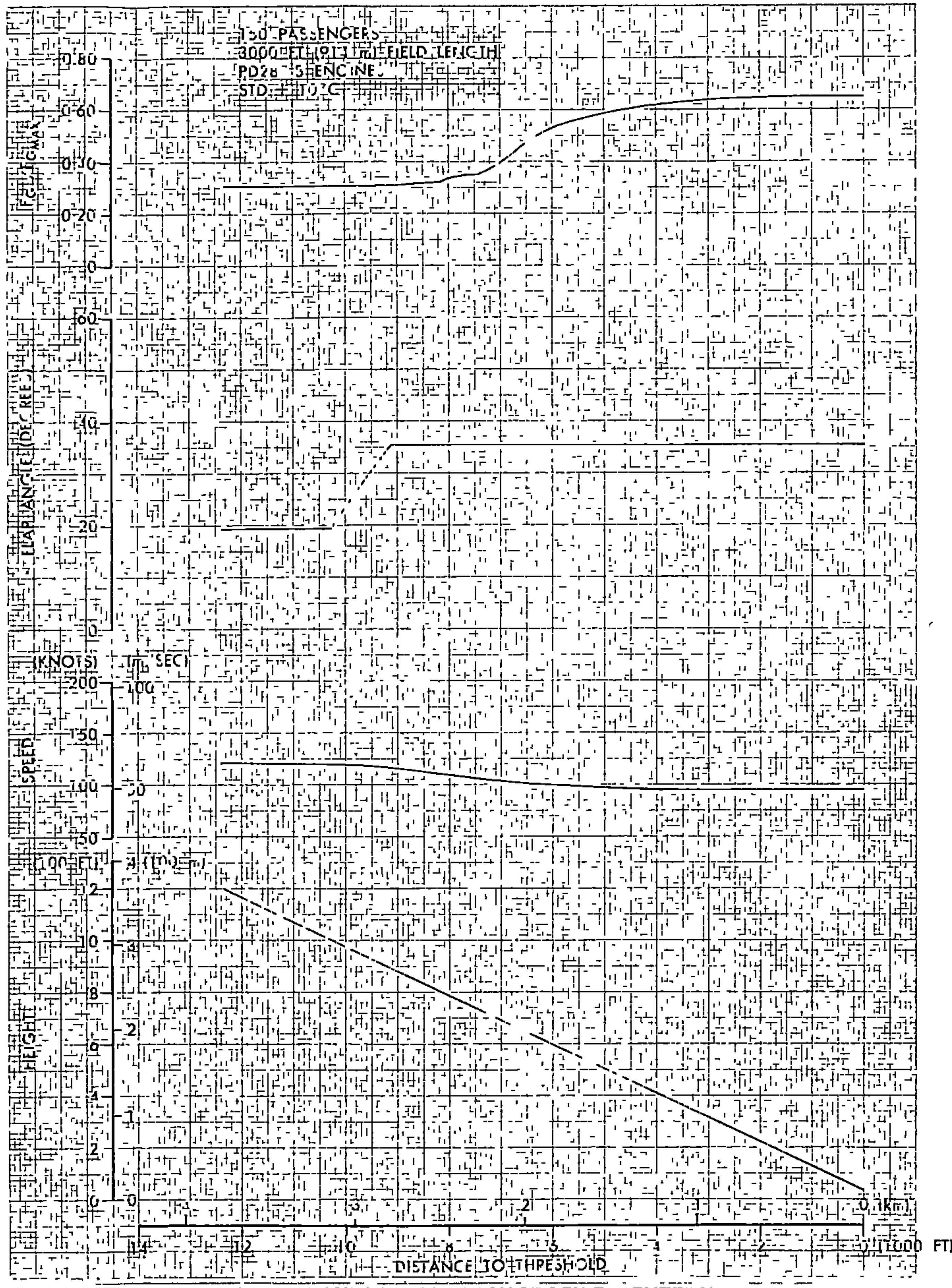


FIGURE 5-20. STANDARD LANDING APPROACH PROFILE – EXTERNALLY BLOWN FLAP AIRCRAFT

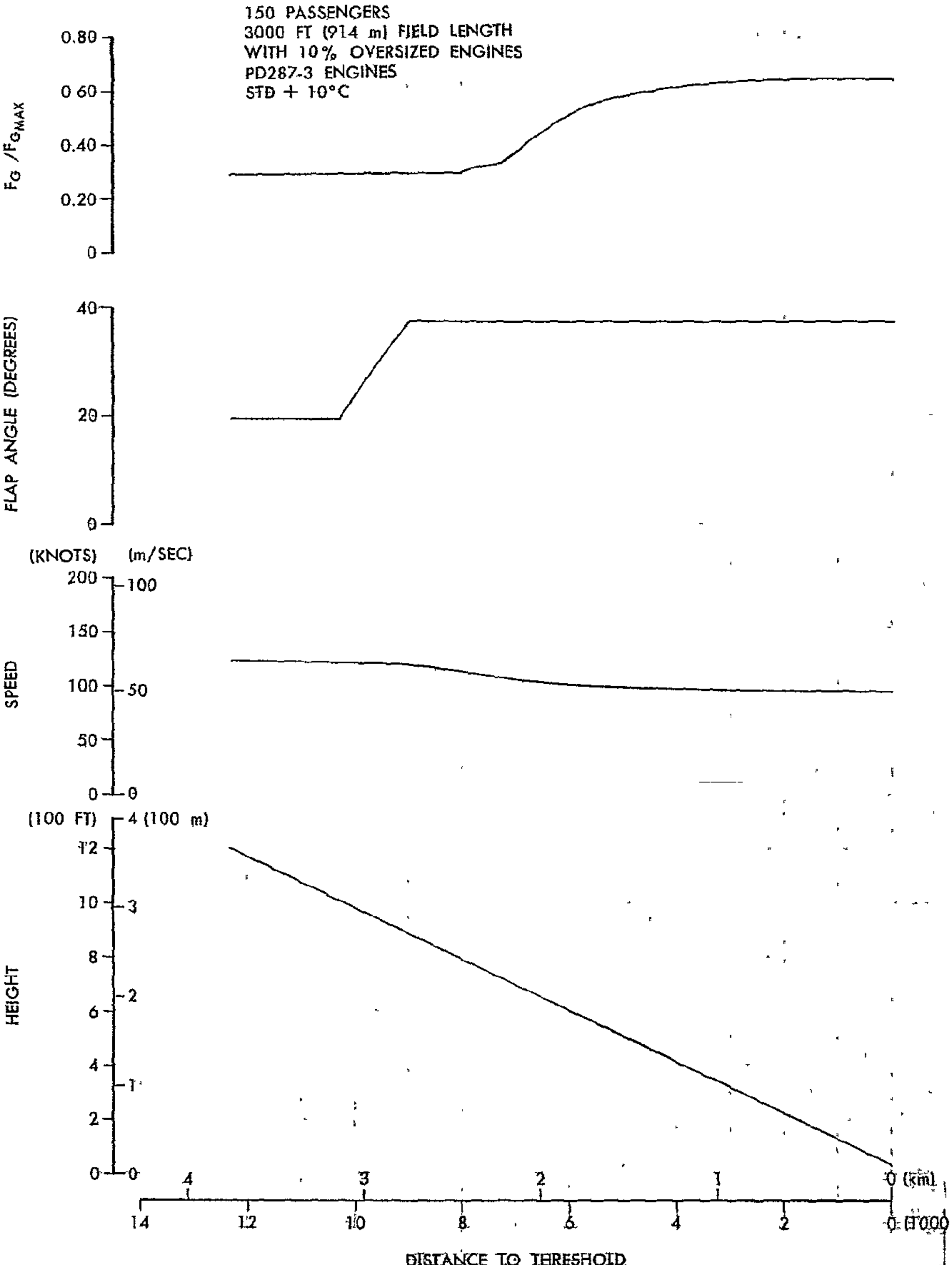


FIGURE 5-21. STANDARD LANDING APPROACH PROFILE – EXTERNALLY BLOWN FLAP AIRCRAFT

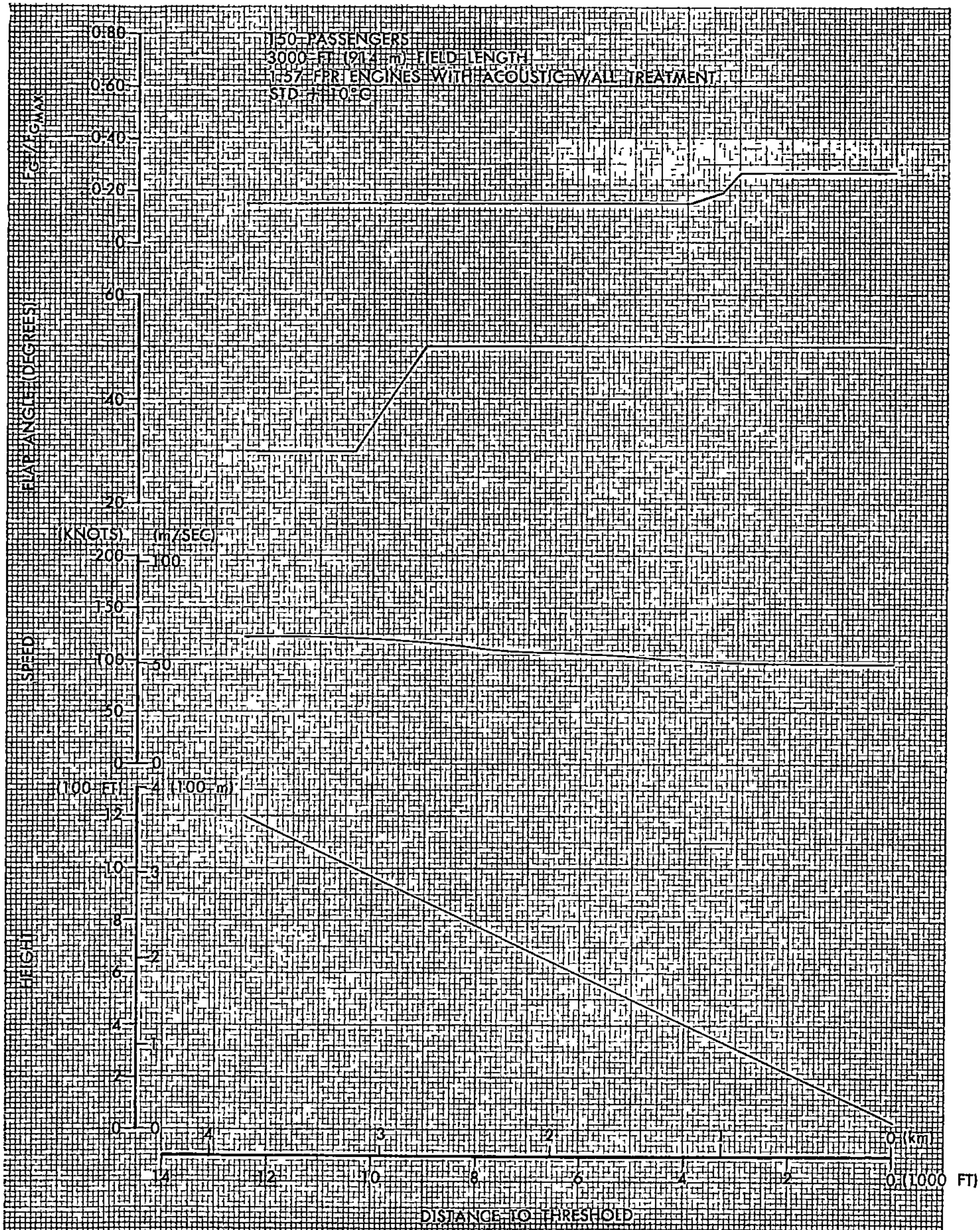


FIGURE 5-22. STANDARD LANDING APPROACH PROFILE – MECHANICAL FLAP AIRCRAFT

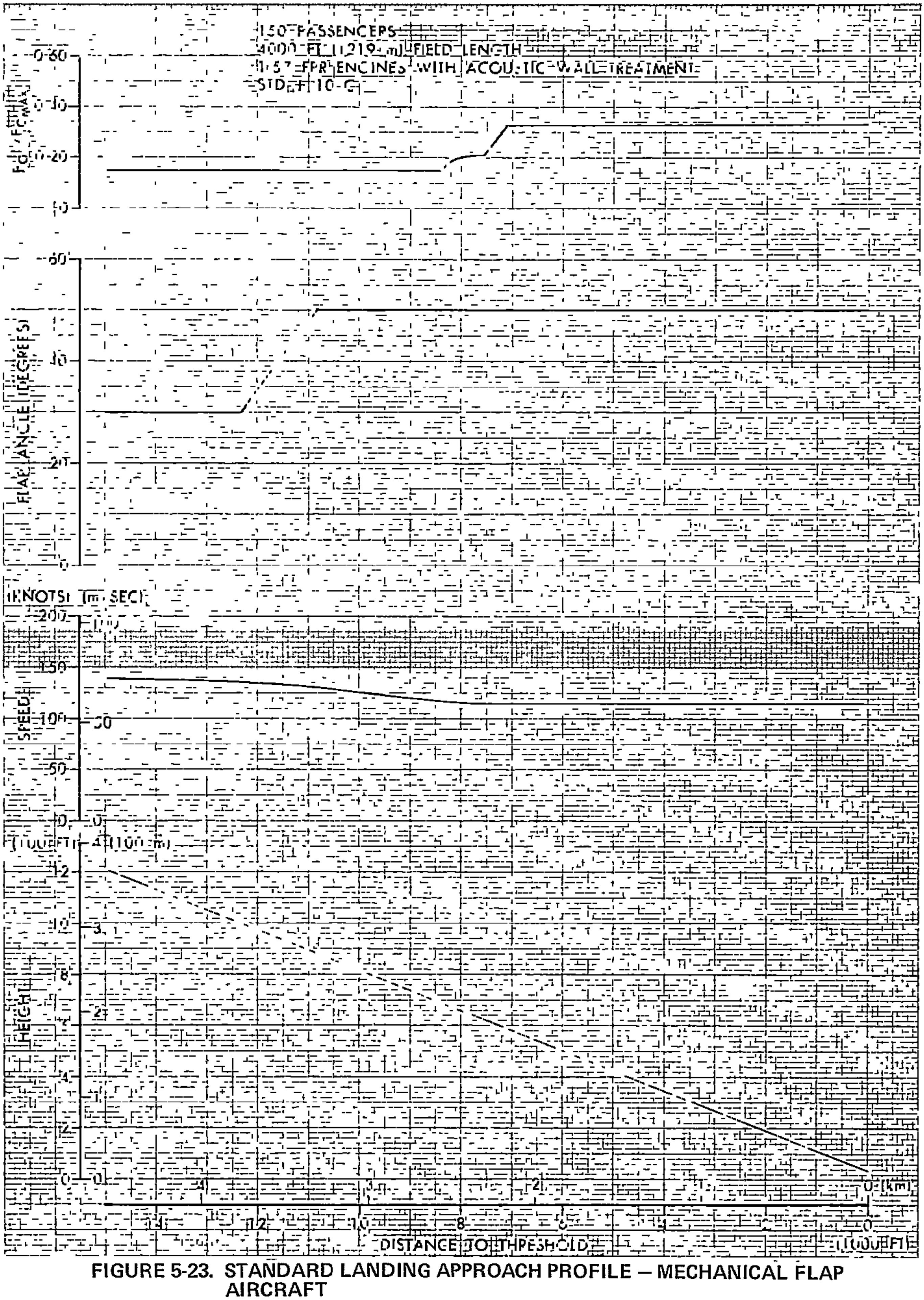


FIGURE 5-23. STANDARD LANDING APPROACH PROFILE – MECHANICAL FLAP AIRCRAFT

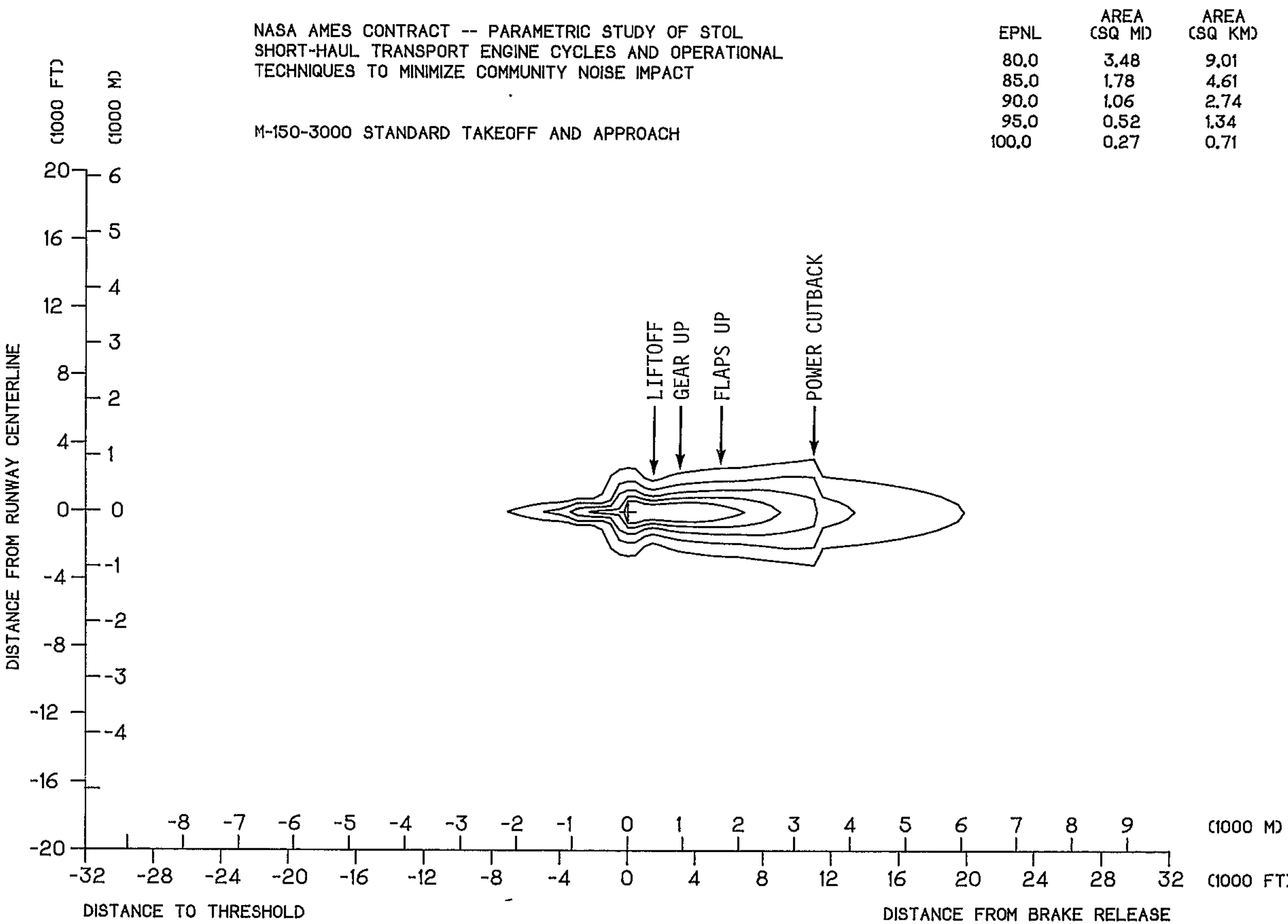

NASA AMES CONTRACT -- PARAMETRIC STUDY OF STOL
SHORT-HAUL TRANSPORT ENGINE CYCLES AND OPERATIONAL
TECHNIQUES TO MINIMIZE COMMUNITY NOISE IMPACT
M-150-3000 STANDARD TAKEOFF AND APPROACH
EPNL
AREA (SQ MI)
AREA (SQ KM)
80.0 3.48 9.01
85.0 1.78 4.61
90.0 1.06 2.74
95.0 0.52 1.34
100.0 0.27 0.71
(1000 FT)
(1000 M)
DISTANCE FROM RUNWAY CENTERLINE
LIFTOFF
GEAR UP
FLAPS UP
POWER CUTBACK
(1000 M)
(1000 FT)
DISTANCE TO THRESHOLD
DISTANCE FROM BRAKE RELEASE

FIGURE 5-24.

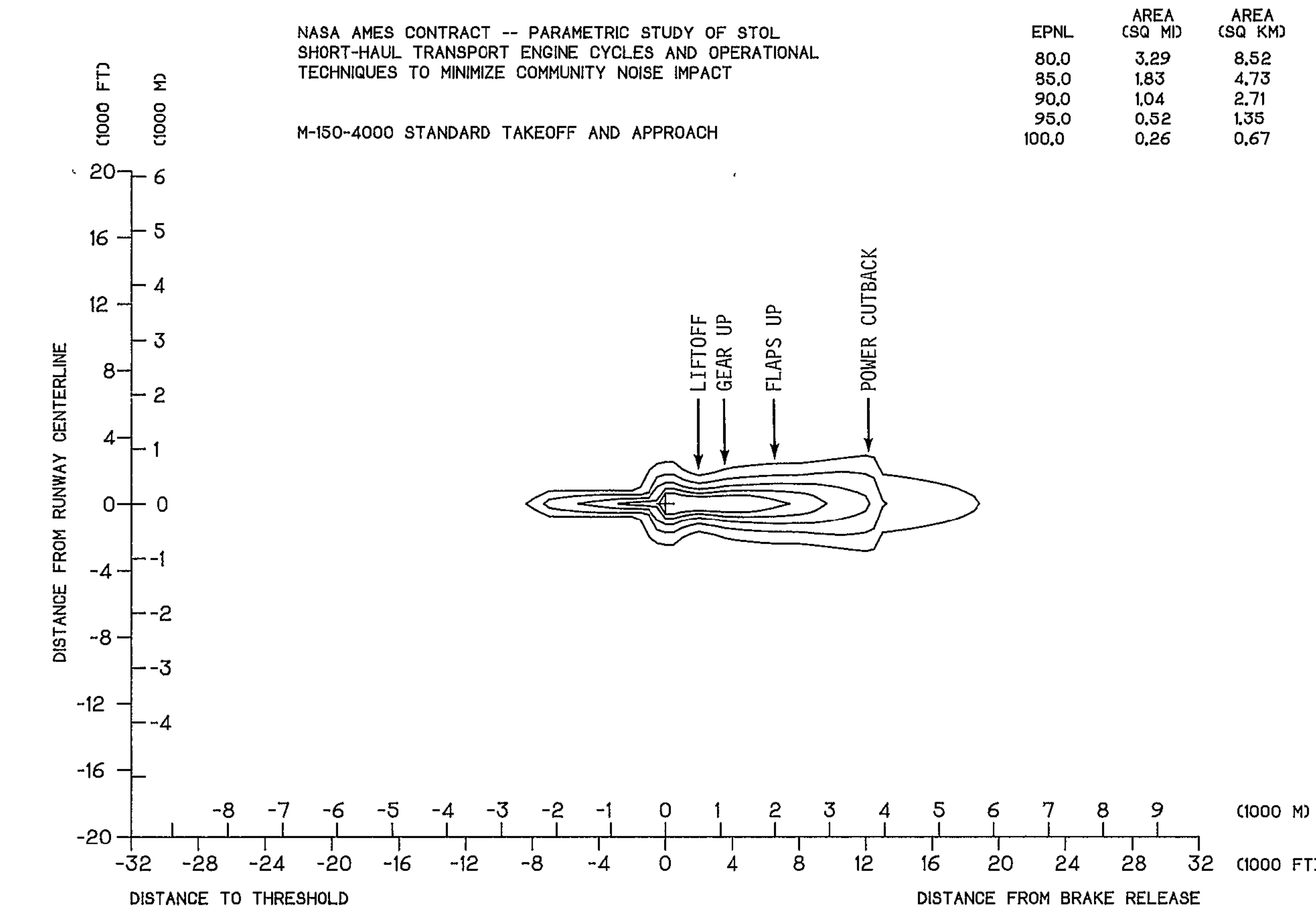

NASA AMES CONTRACT -- PARAMETRIC STUDY OF STOL
SHORT-HAUL TRANSPORT ENGINE CYCLES AND OPERATIONAL
TECHNIQUES TO MINIMIZE COMMUNITY NOISE IMPACT
M-150-4000 STANDARD TAKEOFF AND APPROACH
EPNL
AREA (SQ MI)
AREA (SQ KM)
80.0 3.29 8.52
85.0 1.83 4.73
90.0 1.04 2.71
95.0 0.52 1.35
100.0 0.26 0.67
LIFTOFF
GEAR UP
FLAPS UP
POWER CUTBACK
(1000 FT)
(1000 M)
DISTANCE FROM RUNWAY CENTERLINE
DISTANCE TO THRESHOLD
DISTANCE FROM BRAKE RELEASE
20
16
12
8
4
0
-4
-8
-12
-16
-20
6
5
4
3
2
1
0
-1
-2
-3
-4
-8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 (1000 M)
-32 -28 -24 -20 -16 -12 -8 -4 0 4 8 12 16 20 24 28 32 (1000 FT)

FIGURE 5-25.

NASA AMES CONTRACT -- PARAMETRIC STUDY OF STOL SHORT-HAUL TRANSPORT ENGINE CYCLES AND OPERATIONAL TECHNIQUES TO MINIMIZE COMMUNITY NOISE IMPACT

E-150-3000 STANDARD TAKEOFF AND STANDARD APPROACH

EPNL	AREA (SQ MI)	AREA (SQ KM)
80.0	3.19	8.27
85.0	1.71	4.43
90.0	0.92	2.38
95.0	0.44	1.14
100.0	0.18	0.45

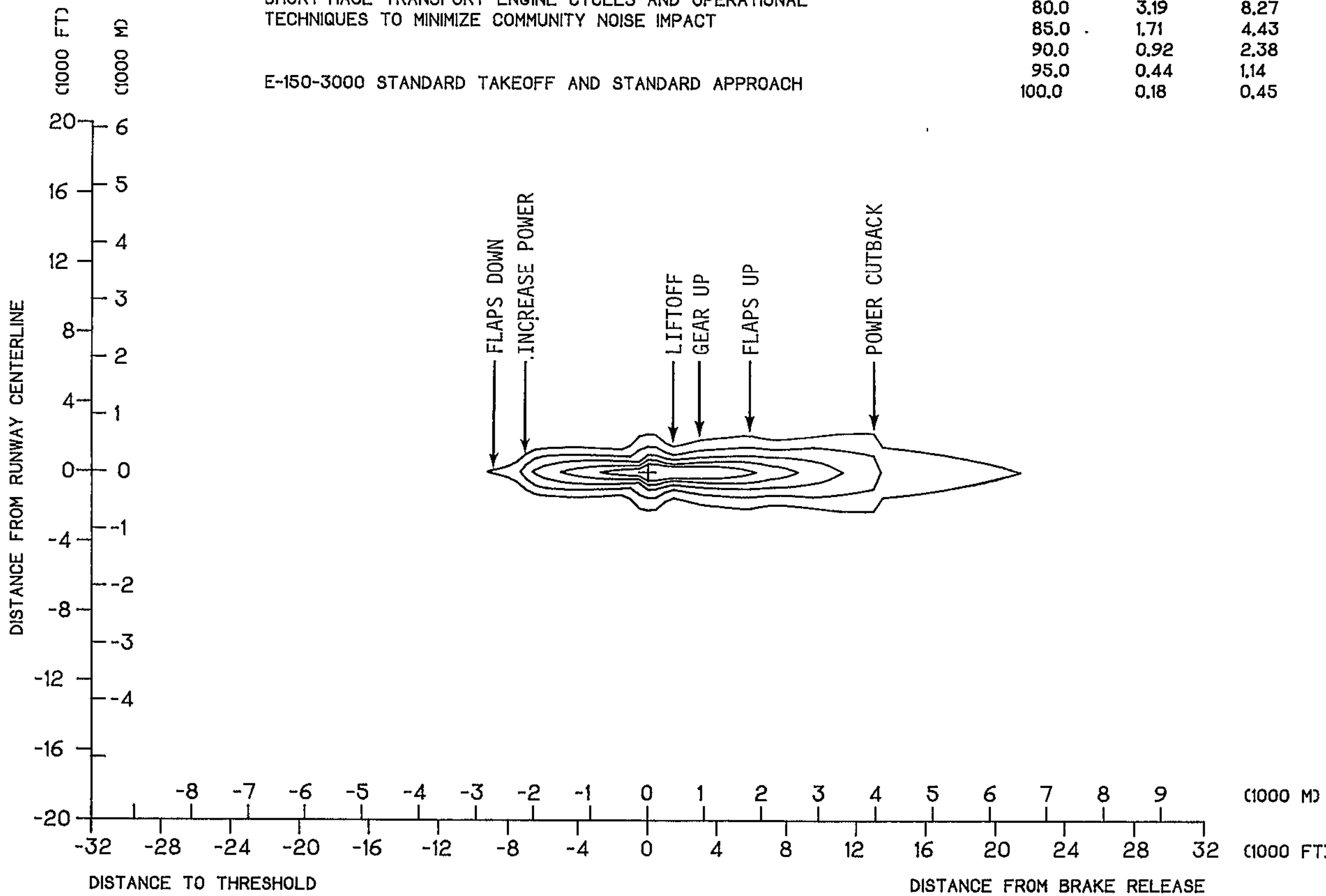


FIGURE 5-6.

Comparing the MF standard contours with the EBF standard contours the most noticeable difference is in the width of the takeoff contours. The higher sideline noise levels produced by the MF aircraft result in wider takeoff noise contours for these aircraft. The landing contours for the MF aircraft are smaller than those for the EBF because of the absence of powered-lift system noise during landing for the MF aircraft. The standard contours for the M-150-3000 and M-150-4000 are almost identical in terms of area but not in shape. The higher T/W of the M-150-4000 aircraft produces a higher climb gradient tending to shorten the takeoff contours. The lower total installed thrust narrows the takeoff contours. The M-150-4000 landing contours, however, are longer and wider due to the shallower approach flight path angles associated with longer field length.

The standard noise contours for the EBF with 5 percent and 10 percent oversized engines are shown in Figures 5-27 and 5-28. The improved climb characteristics of the EBF aircraft with oversized engines more than offset the small sideline noise penalty associated with oversizing the engines; therefore, the corresponding noise contour areas are smaller for the aircraft with oversized engines.

A noise impact evaluation was made for each aircraft, based on the standard takeoff and approach procedure, and a uniform population density distribution (Reference Figure 5-11A). The results of this evaluation, relative to the E-150-3000 aircraft, are as follows:

NASA AMES CONTRACT -- PARAMETRIC STUDY OF STOL SHORT-HAUL TRANSPORT ENGINE CYCLES AND OPERATIONAL TECHNIQUES TO MINIMIZE COMMUNITY NOISE IMPACT

E-150-3000 5 PERCENT OVERSIZED ENGINES

EPNL	AREA (SQ MI)	AREA (SQ KM)
80.0	3.02	7.82
85.0	1.60	4.15
90.0	0.85	2.21
95.0	0.41	1.07
100.0	0.17	0.44

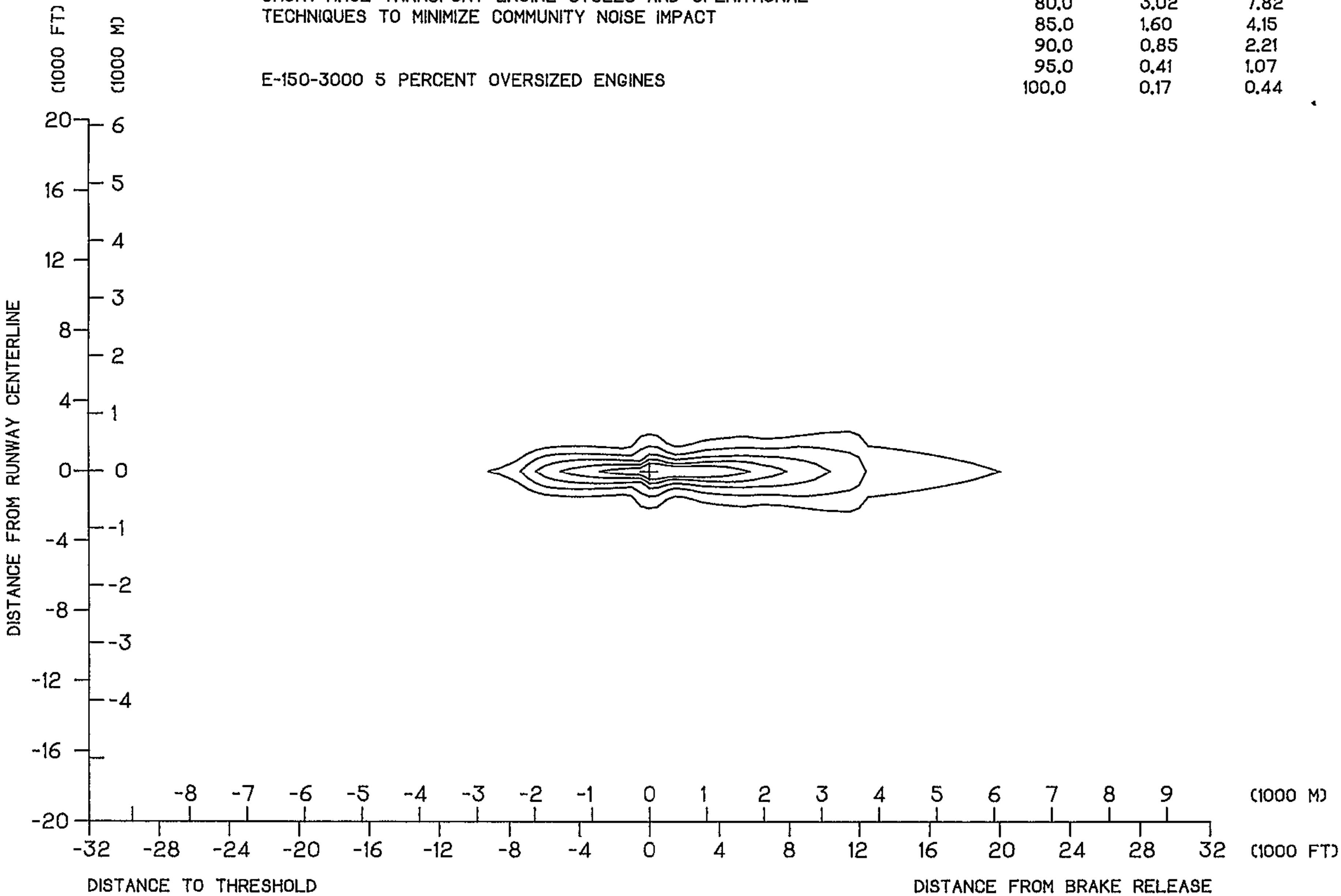


FIGURE 5-27.

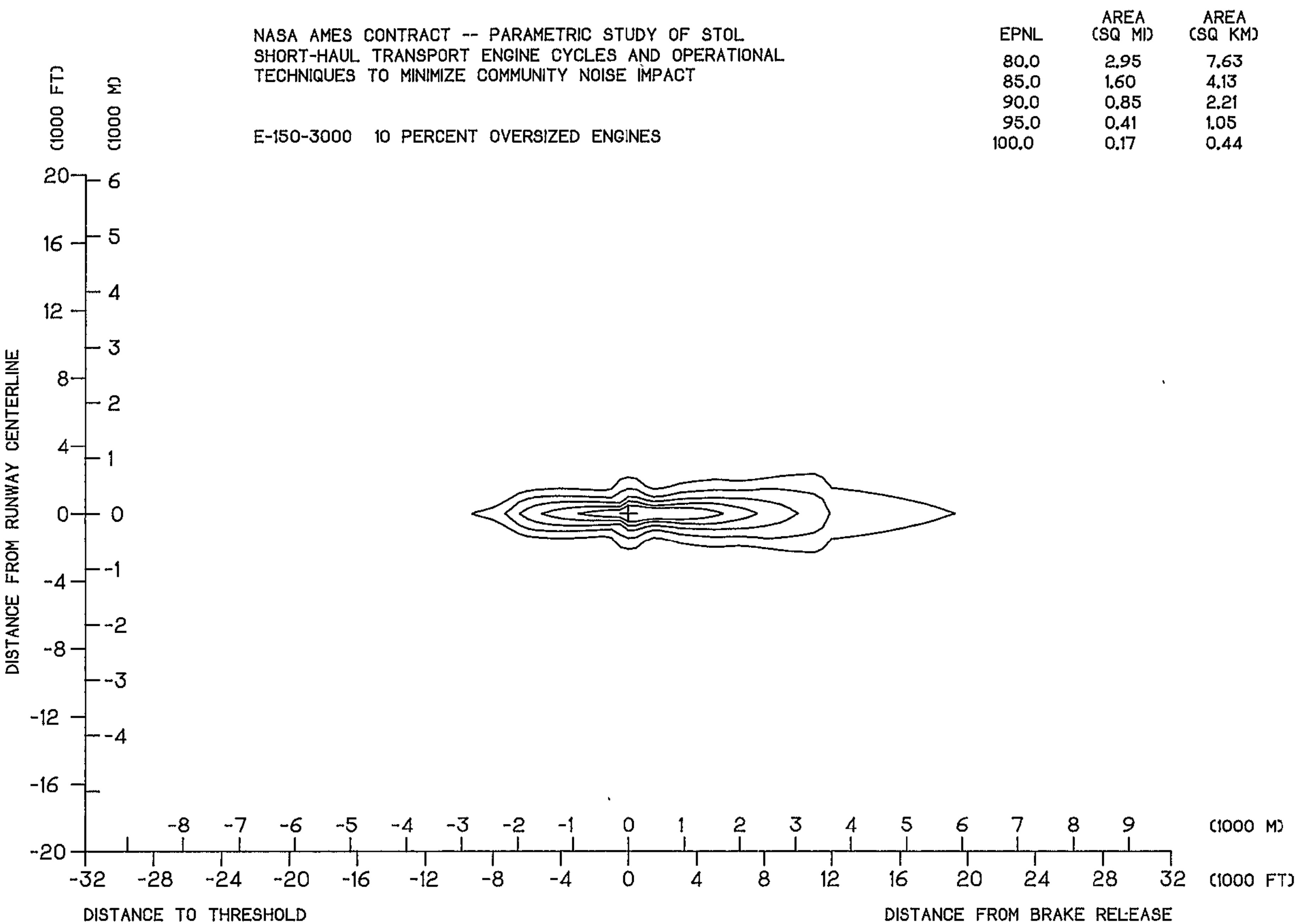

NASA AMES CONTRACT -- PARAMETRIC STUDY OF STOL SHORT-HAUL TRANSPORT ENGINE CYCLES AND OPERATIONAL TECHNIQUES TO MINIMIZE COMMUNITY NOISE IMPACT
E-150-3000 10 PERCENT OVERSIZED ENGINES
EPNL | AREA (SQ MI) | AREA (SQ KM)
80.0 | 2.95 | 7.63
85.0 | 1.60 | 4.13
90.0 | 0.85 | 2.21
95.0 | 0.41 | 1.05
100.0 | 0.17 | 0.44
(1000 FT)
(1000 M)
DISTANCE FROM RUNWAY CENTERLINE
20
16
12
8
4
0
-4
-8
-12
-16
-20
6
5
4
3
2
1
0
-1
-2
-3
-4
-8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 (1000 M)
-32 -28 -24 -20 -16 -12 -8 -4 0 4 8 12 16 20 24 28 32 (1000 FT)
DISTANCE TO THRESHOLD
DISTANCE FROM BRAKE RELEASE

FIGURE 5-28.

Aircraft	Relative Percent of People Highly Annoyed
M-150-3000	+ 9.3
M-150-4000	+ 8.7
E-150-3000	0
EBF (5% Oversized Engines)	- 6.0
EBF (10% Oversized Engines)	- 8.1

The results show the impact of the two MF aircraft to be essentially the same. Since the M-150-4000 has a lower direct operating cost, and uses less mission fuel, it was chosen along with the E-150-3000 aircraft to further evaluate the use of operational techniques for noise reduction. The EBF with 10 percent oversized engines was also evaluated at one of the study airports.

5.5 Parametric Study of Operational Techniques

5.5.1 Objectives - A parametric study of takeoff and landing operational techniques for noise reduction was conducted to narrow down the number of techniques to be evaluated at each airport. The parametric study resulted in the selection of a takeoff and landing operational procedure, for each aircraft, which would produce the lowest noise impact based on a uniform population density. These low-impact procedures would provide a starting point for determining the best operational procedures to use at each airport to produce the minimum community noise impact.

5.5.2 Evaluation Procedure - Takeoff and landing operational techniques were evaluated on a noise impact basis assuming a uniform population density. This was the same procedure used for the evaluations in Section 5.4.4. The evaluation started with the standard takeoff and approach procedure for each aircraft and the effect of varying each operational parameter was studied independently. The resulting change in noise impact was compared to the noise impact produced by the standard takeoff and approach procedure.

The philosophy taken concerning the variations of the takeoff and landing flight profiles was that the flight procedures should be compatible with both VFR and IFR operations. On this basis, the following operational constraints were imposed:

Takeoff

1. No turns or thrust cutbacks were made below a height of 500 feet (152 m).
2. Amount of thrust cutback limited so that all-engine climb gradient $\geq$ 4%; one-engine-out climb gradient $\geq$ 0%.

The all-engines-operating 4 percent gradient requirement was found to be critical for the four-engine EBF aircraft and the zero gradient with one engine failed was critical for the MF twin-engine aircraft.

3. Combination maneuvers were avoided, i.e., changing thrust level during a turn or changing flap setting during a turn.

Landing

1. At a height of 500 feet (152 m) the aircraft should be essentially stabilized in the final landing configuration. Therefore, no changes in flap angle, glide slope or turns were made below a height of 500 feet (152 m).
2. The final approach descent rate was limited to a maximum of 1000 ft/min (5.1 m/sec).

5.5.3 Takeoff Techniques - Takeoff procedures incorporating variations in flap retraction height, flap retraction rate, thrust cutback height and thrust cutback amount were evaluated. The noise impact, based on a uniform population density, produced by each of these techniques, relative to the impact produced by the standard takeoff procedure is shown in Figures 5-29 through 5-32. The results show, for the EBF aircraft, that flap retraction should occur as soon as practical after liftoff in order to minimize propulsive-lift-system noise. The noise impact for the MF aircraft was not particularly sensitive to flap retraction height or rate. Early flap retraction was found to give a slight reduction in noise impact. Flap retraction rate should be kept low to minimize hydraulic power requirements. A rate of 3 deg/sec (0.05 rad/sec) was found to be the lowest rate which did not increase noise impact. For both aircraft, thrust should be cut back to

EFFECT OF FLAP RETRACTION HEIGHT

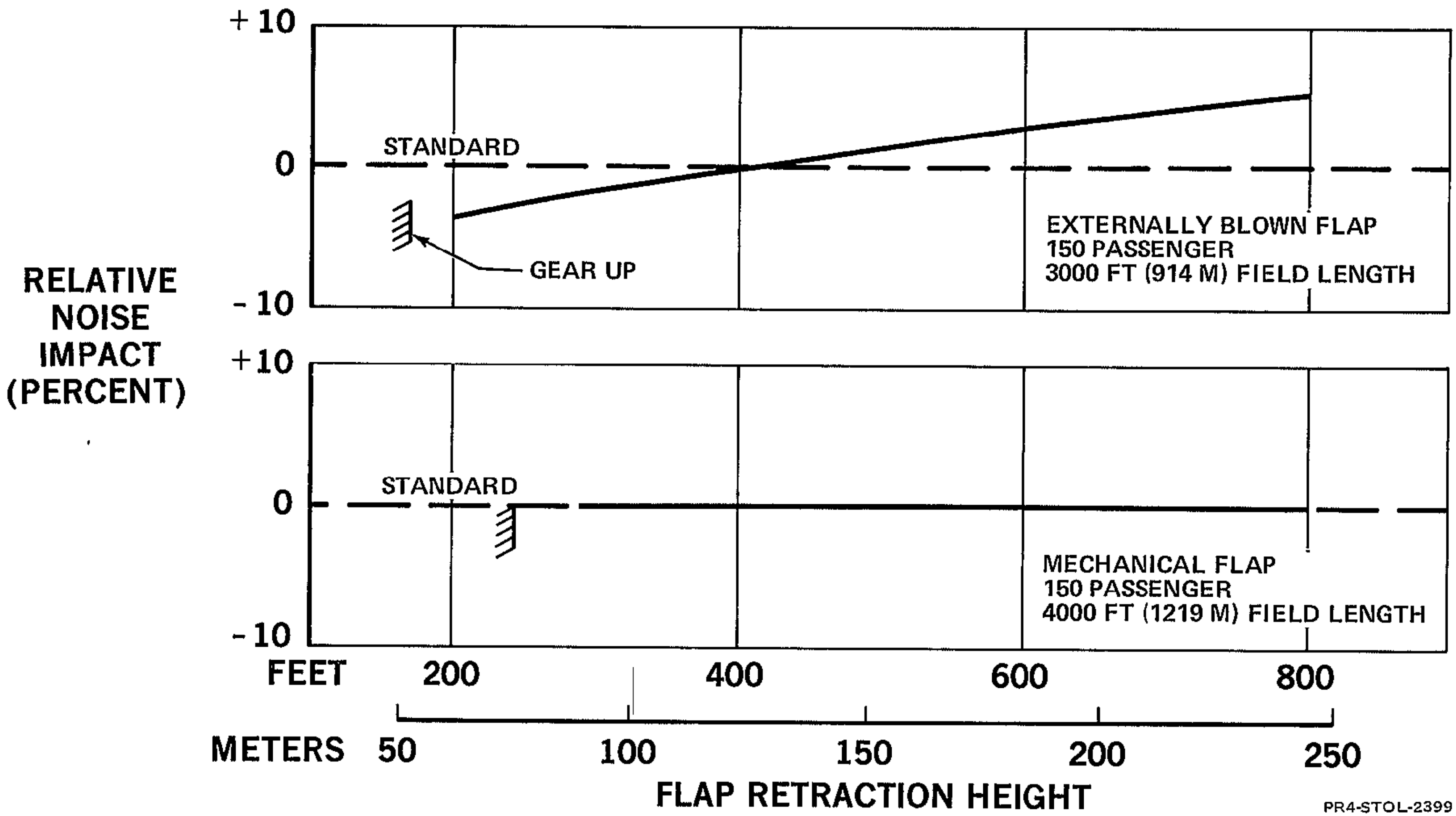
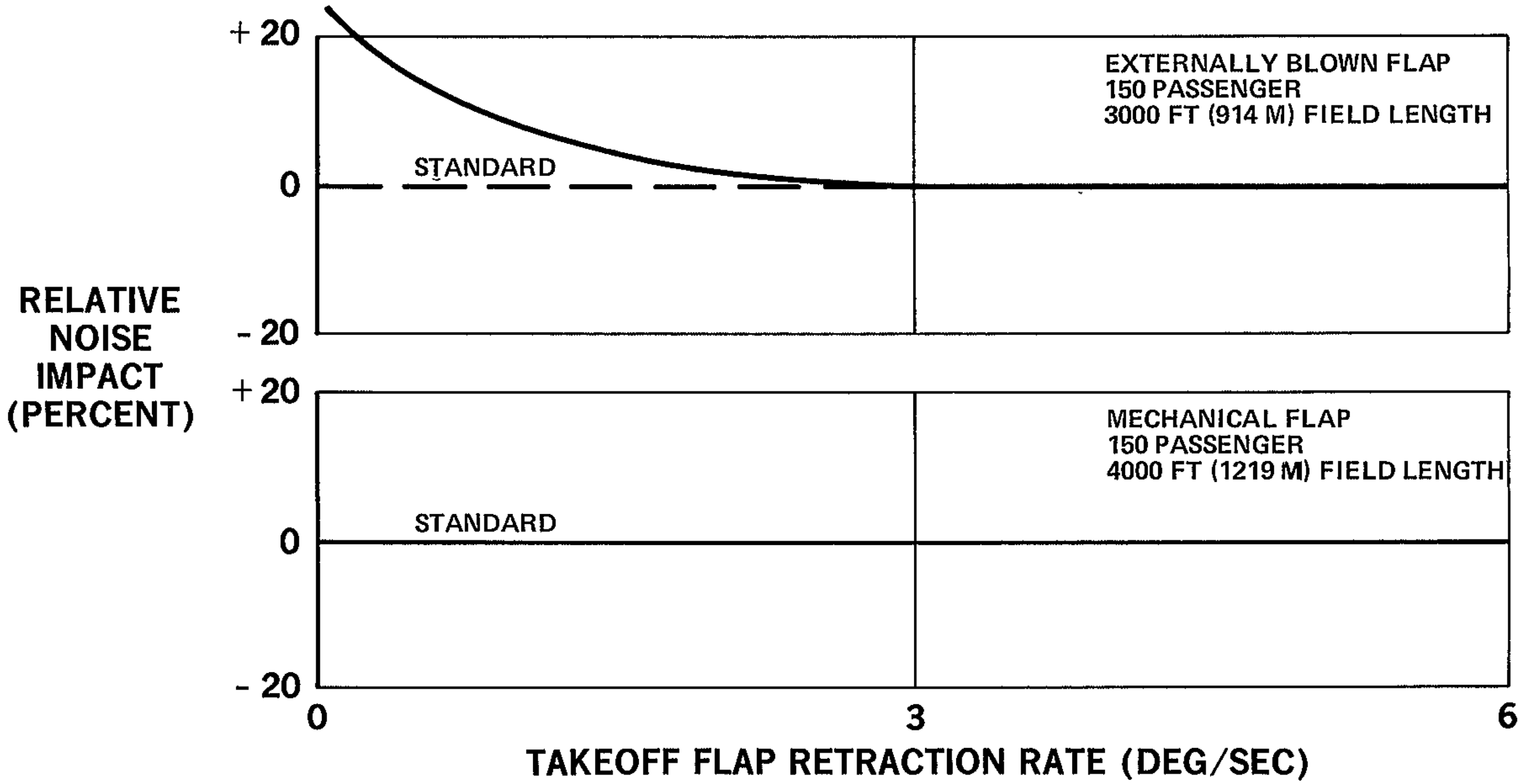


FIGURE 5-29.

EFFECT OF TAKEOFF FLAP RETRACTION RATE



PR4-STOL-2400

FIGURE 5-30.

EFFECT OF TAKEOFF THRUST CUTBACK HEIGHT

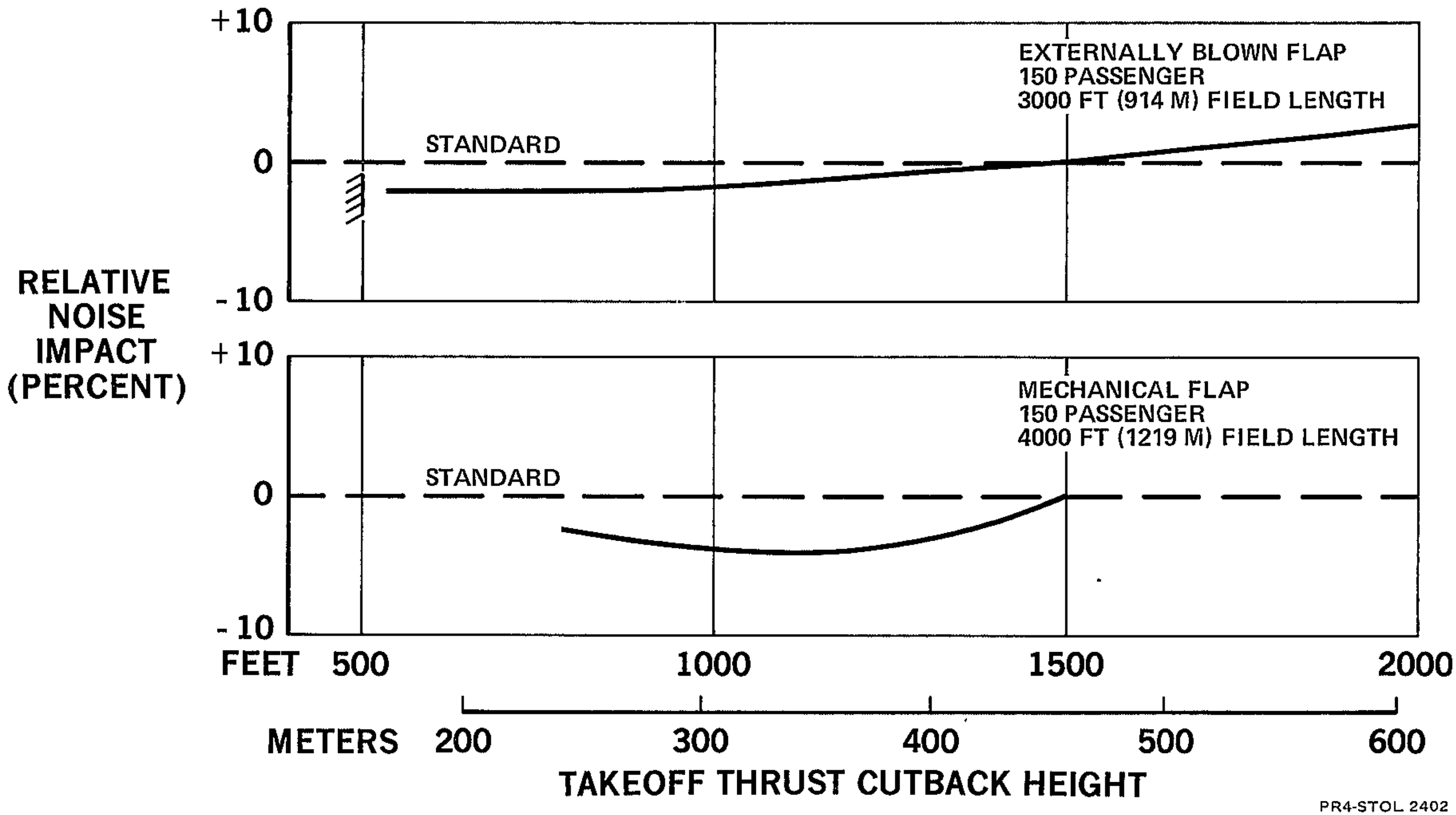
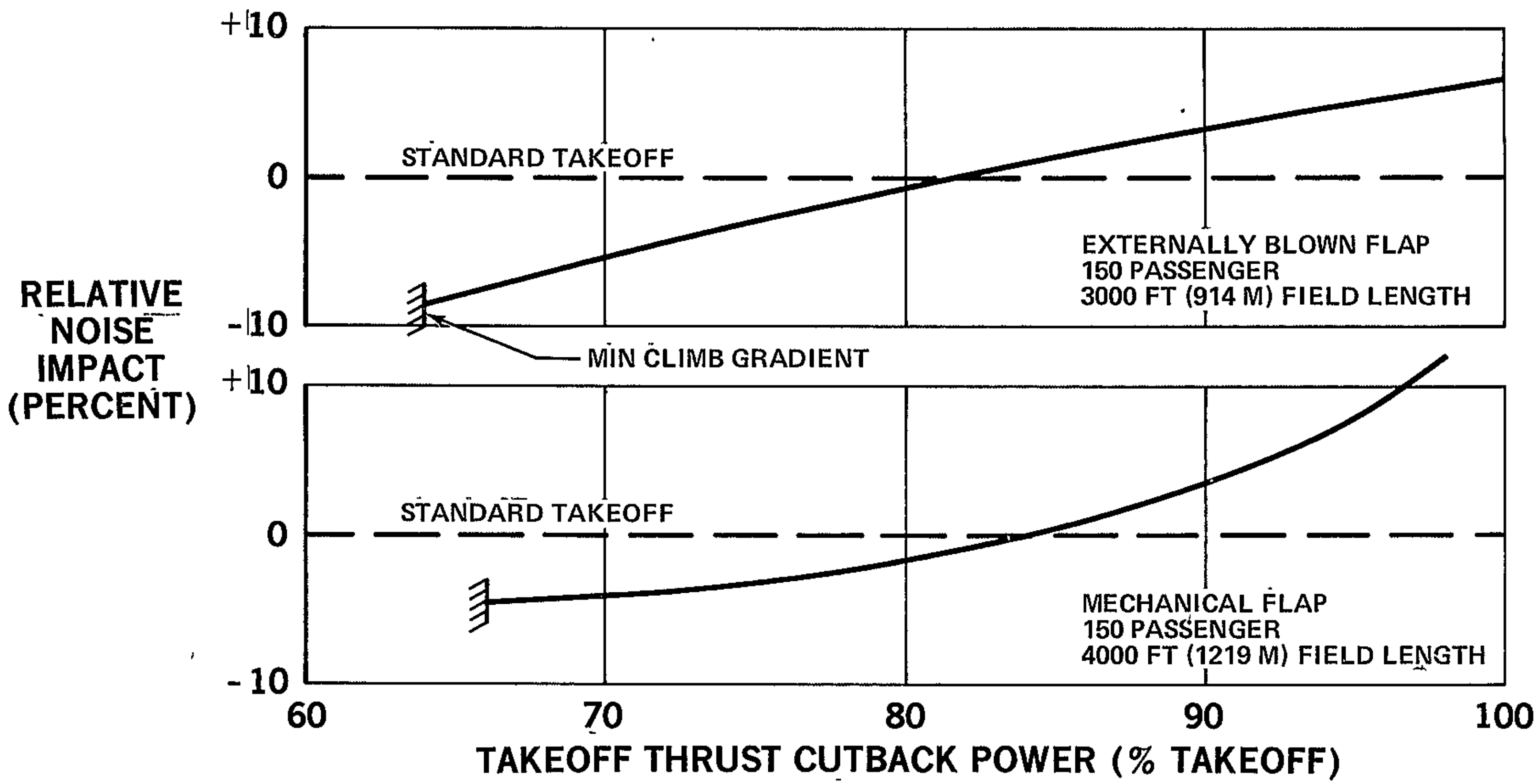


FIGURE 5-31.

EFFECT OF TAKEOFF THRUST CUTBACK POWER



PR4-STOL-2401

FIGURE 5-32.

the lowest level consistent with safe aircraft operation. Selection of thrust cutback height is based on a tradeoff between minimizing noise close to or far from the airport. The particular value selected is strongly influenced by the particular aircraft performance and noise generation characteristics. From these results, a low-impact operational procedure which produced the lowest noise impact based on a uniform population distribution was developed for each aircraft. The selected low-impact takeoff operational procedure for each aircraft is defined as follows:

		E-150-3000	M-150-4000
Flap Retraction Height	Ft(m)	200 (70)	250 (76)
Flap Retraction Rate	Deg/Sec (Rad/Sec)	3 (0.0525)	3 (0.0525)
Thrust Cutback Height	Ft(m)	1000 (305)	750 (229)
Thrust Cutback Power	%	64	66

5.5.4 Approach Techniques - The small size of the noise contours for the standard approach procedure was a limiting factor in evaluating potential approach operational techniques for noise reduction. The techniques evaluated were limited to two segment glide slopes and decelerating approaches.

The use of a two-segment glide slope did not prove to be useful for noise levels above 80 EPNdB because of the low aircraft noise levels. The approach noise contours for both aircraft were fully developed within the second segment of the approach, so the first or steep glide slope segment had no effect on the noise contours. The first- and second-segment glide slope intersection height was chosen to be 750 feet (229 m) for the two-segment technique in order that stabilization be achieved prior to reaching a height of 500 feet (152 m).

The effect of descent rate is shown in Figure 5-33. This figure shows that as the descent rate increases there is a reduction in noise impact. Based on these results, the descent rate chosen for the low-impact approach procedure was 1000 ft/min (5.1 m/sec). The landing flap extension rate was held to a minimum to permit a low power setting while decelerating. The selected low-impact approach procedure for each aircraft is defined as follows:

		E-150-3000	M-150-4000
Descent Rate	Ft/Min (m/sec)	1000 (5.1)	1000 (5.1)
Flap Extension Rate	Deg/Sec (rad/sec)	1 (0.0175)	1 (0.0175)
Approach Power		Idle	Idle

The flight profiles for the low-impact procedure, for the E-150-3000 and M-150-4000 aircraft, are shown in Figures 5-34 through 5-37. The noise contours corresponding to the low-impact procedure, for the E-150-3000 and M-150-4000 aircraft, are shown in Figures 5-38 and 5-39. A comparison of the standard and low-impact procedure, based on noise contour areas is included below.

EPNL Contour Area - Mi^2 (Km^2)

EPNL Contour	E-150-3000		M-150-4000	
(dB)	Standard	Low-Impact	Standard	Low-Impact
80	3.19(8.27)	2.61(6.77)	3.29(8.52)	2.77(7.17)
85	1.71(4.43)	1.22(3.16)	1.83(4.73)	1.45(3.75)
90	0.92(2.38)	0.73(1.90)	1.04(2.71)	0.82(2.13)
95	0.44(1.14)	0.38(0.98)	0.52(1.35)	0.50(1.30)
100	0.18(0.45)	0.18(0.45)	0.26(0.67)	0.26(0.67)

5.5.5 Summary of Results - Takeoff and approach operational procedures were developed for the EBF and MF aircraft which produce the lowest noise impact based on a uniform population density. The small size of the low-impact approach noise contours, relative to the takeoff noise contours implies that little if any reduction in noise impact can be obtained at an actual airport by

EFFECT OF APPROACH DESCENT RATE

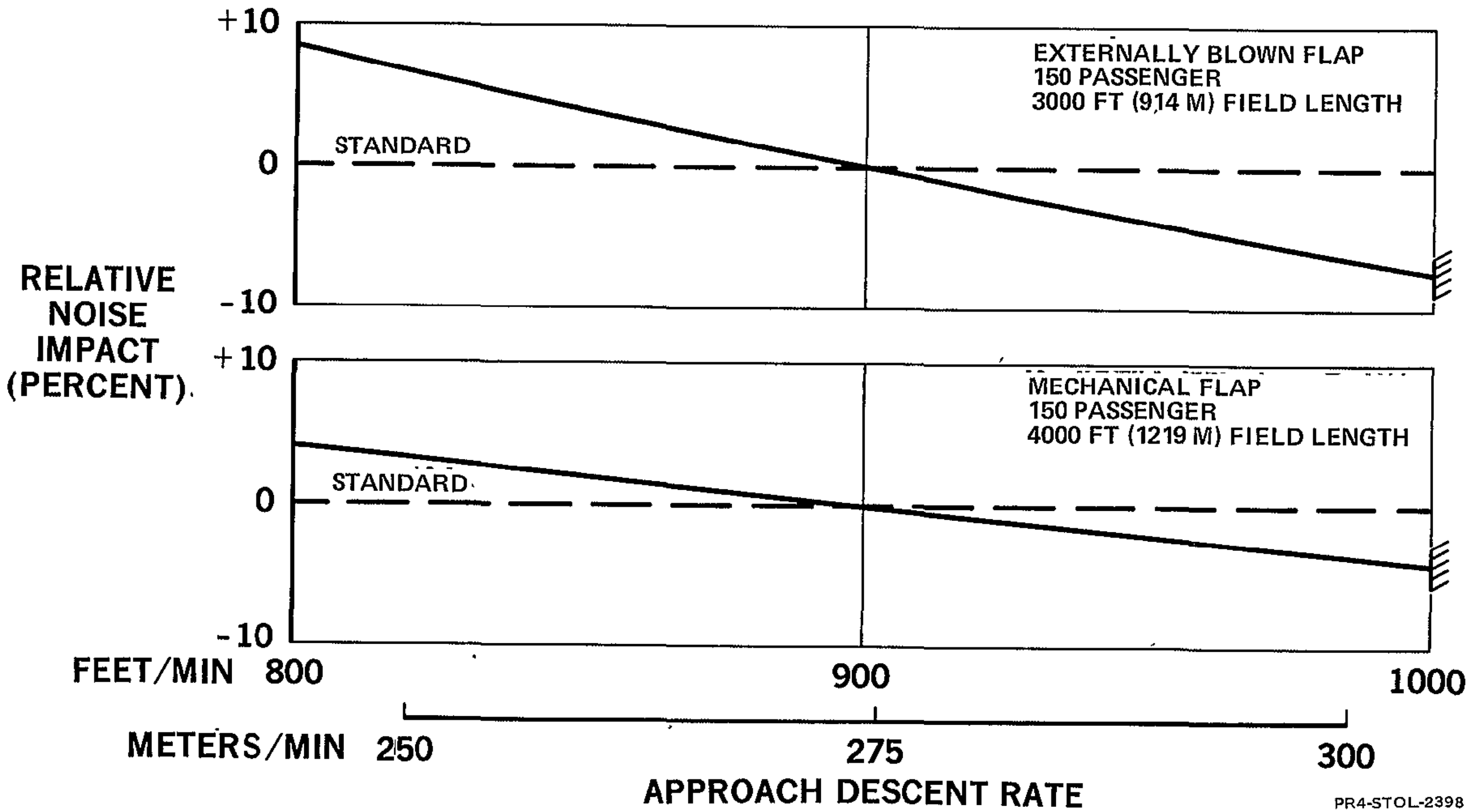


FIGURE 5-33.

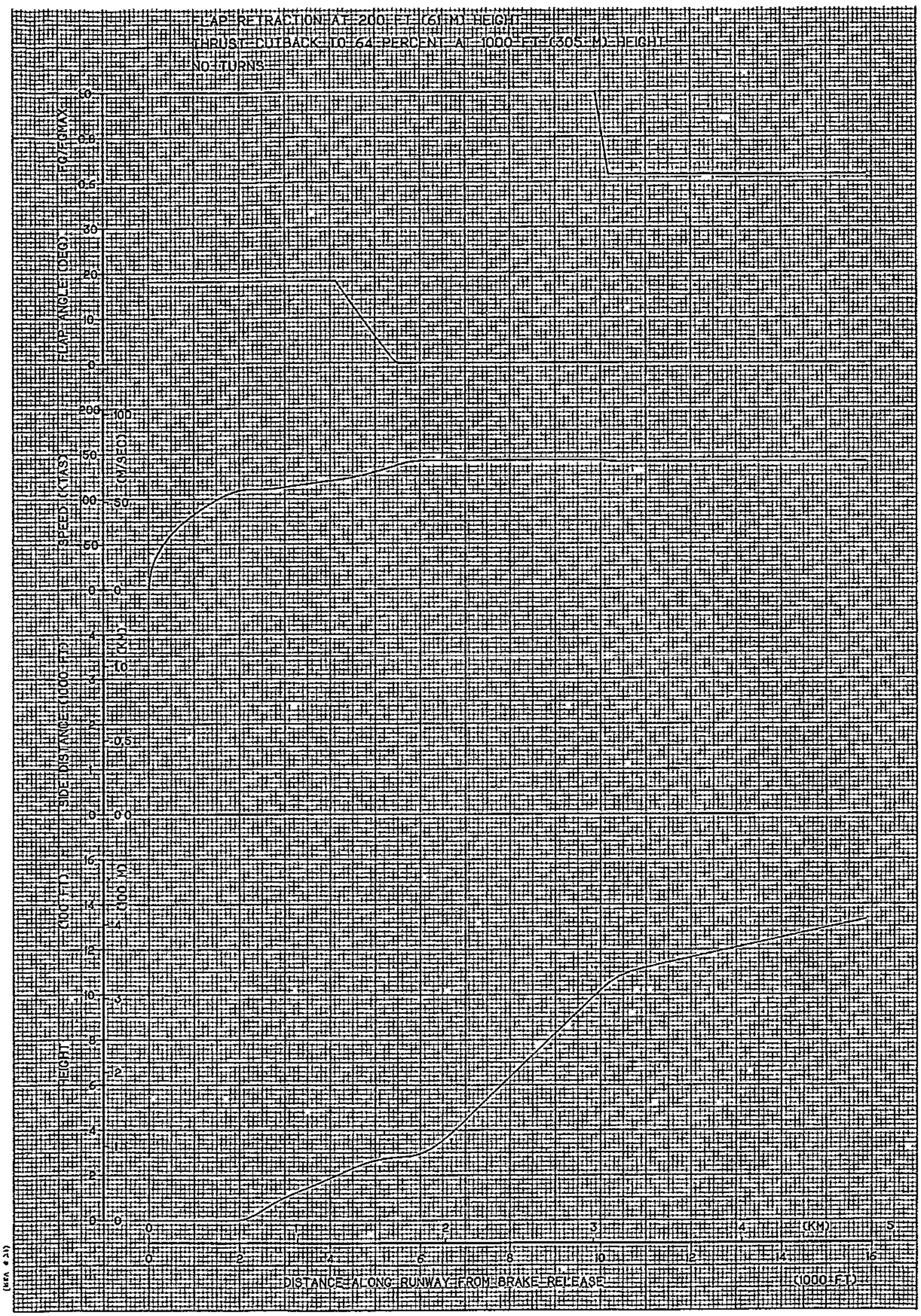


FIGURE 5-34 LOW IMPACT TAKEOFF PROFILE E-150-3000 AIRCRAFT

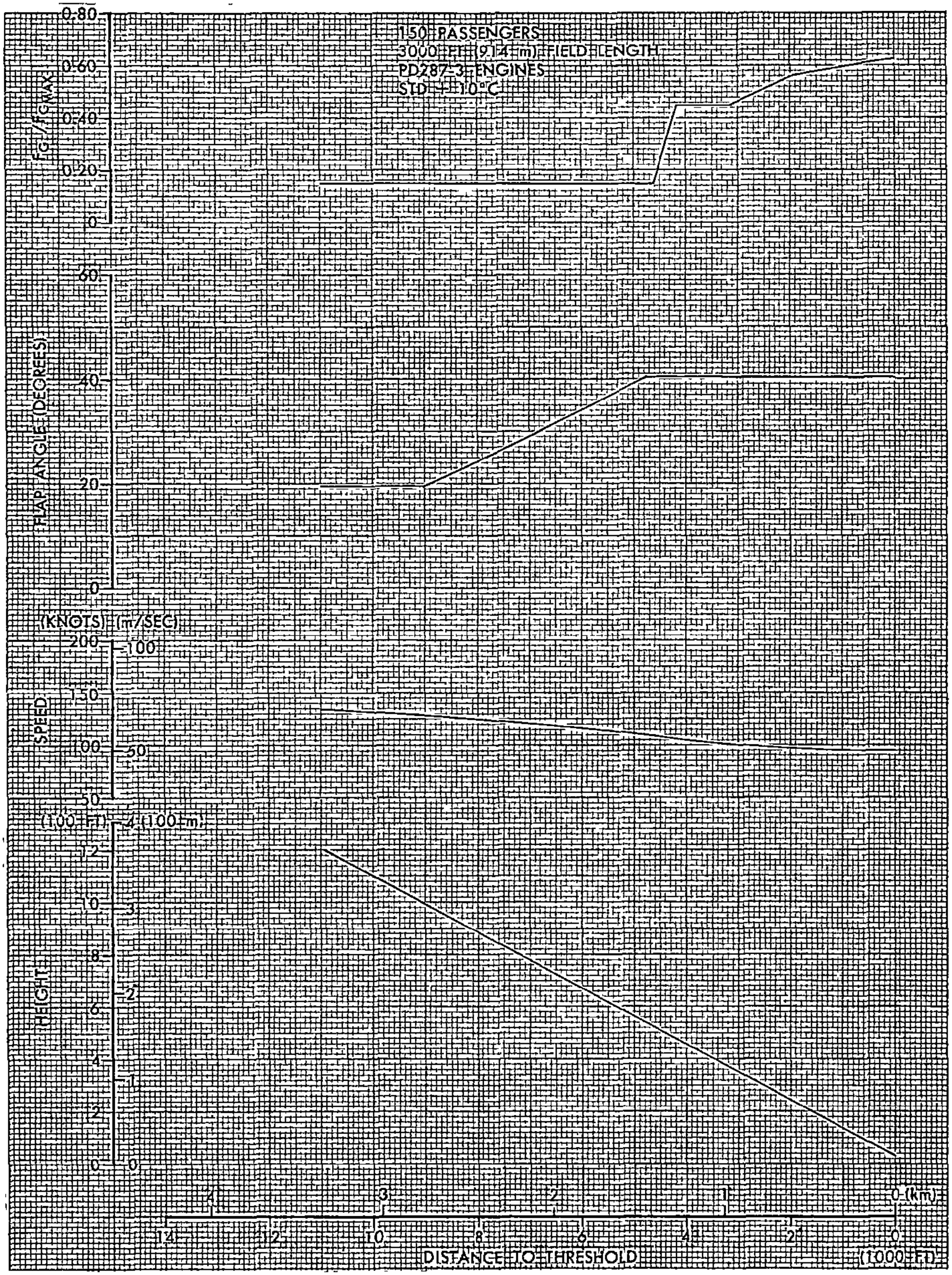


FIGURE 5-35. MINIMUM IMPACT LANDING APPROACH PROFILE—EXTERNALLY BLOWN FLAP AIRCRAFT

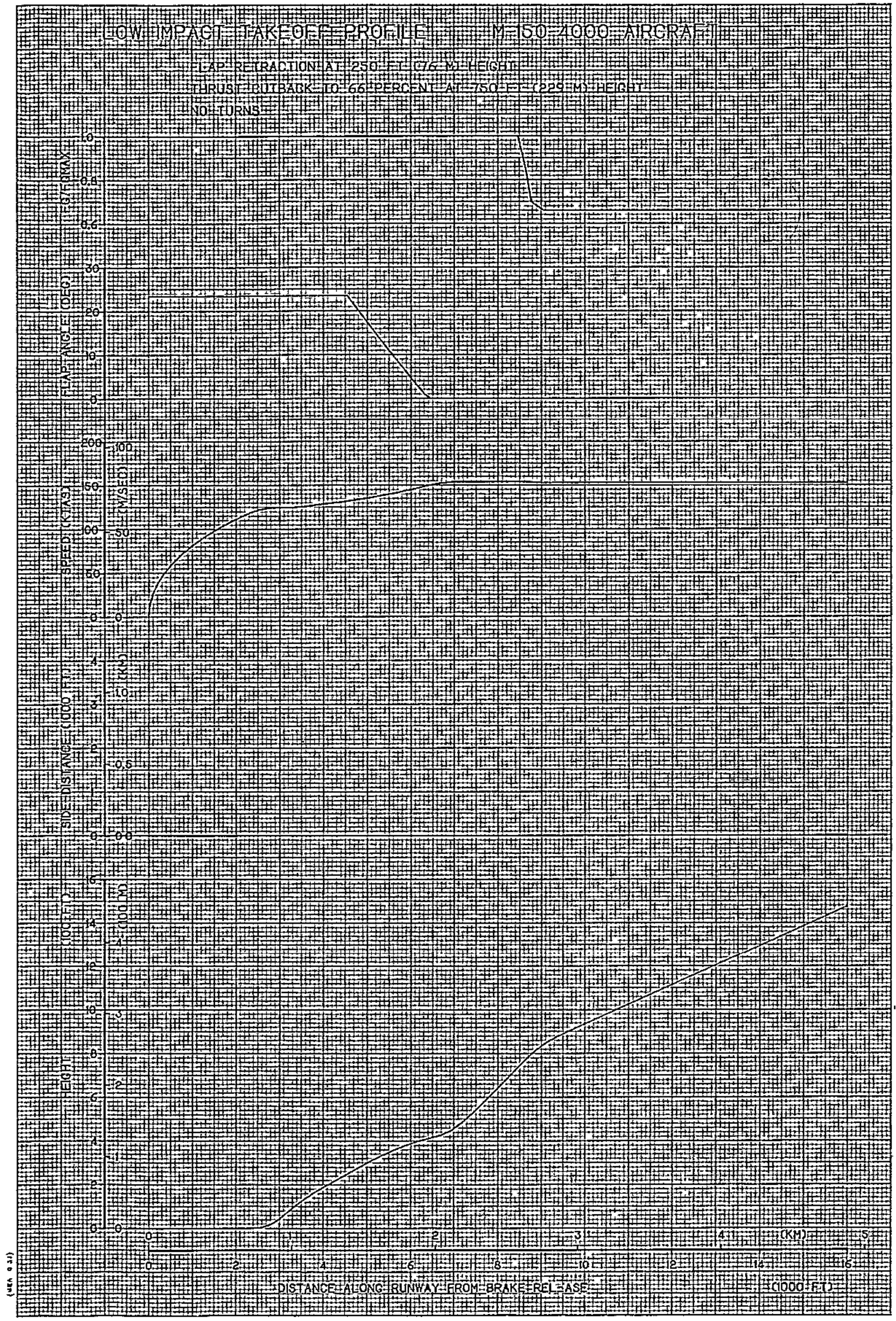

LOW IMPACT TAKEOFF PROFILE M-150-4000 AIRCRAFT
FLAP RETRACTION AT 250 FT (76 M) HEIGHT
THRUST CUTBACK TO 66 PERCENT AT 750 FT (229 M) HEIGHT
NO TURNS
FLAP ANGLE (DEG)
SPEED (KTAS)
(M/SEC)
SIDE DISTANCE (1000 FT)
(KM)
HEIGHT (100 FT)
(100 M)
DISTANCE ALONG RUNWAY FROM BRAKE RELEASE (1000 FT)
(KM)

FIGURE 5-36.

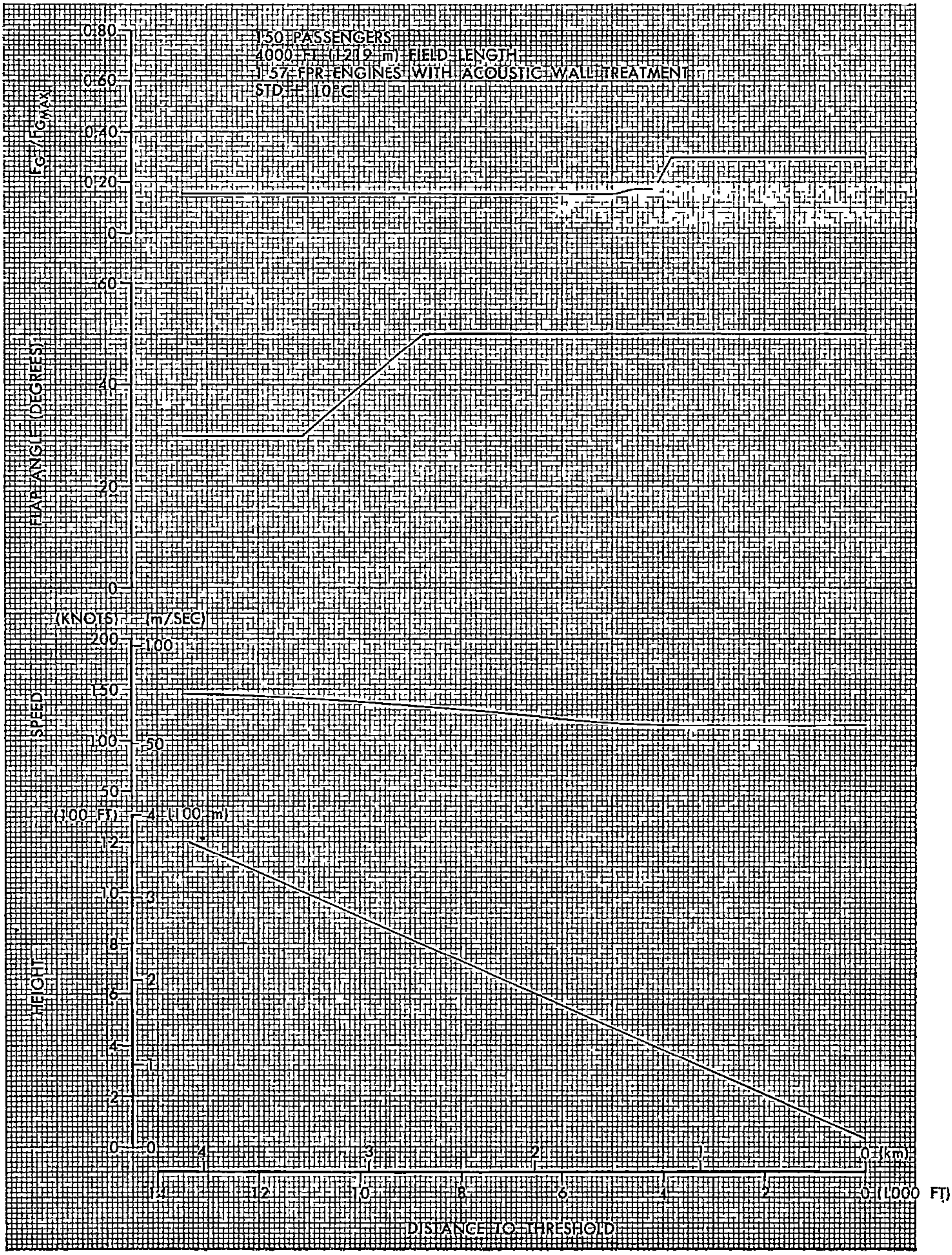


FIGURE 5-37. MINIMUM IMPACT LANDING APPROACH PROFILE—MECHANICAL FLAP AIRCRAFT

NASA AMES CONTRACT -- PARAMETRIC STUDY OF STOL
SHORT-HAUL TRANSPORT ENGINE CYCLES AND OPERATIONAL
TECHNIQUES TO MINIMIZE COMMUNITY NOISE IMPACT

E-150-3000 LOW IMPACT OPERATIONAL PROCEDURE NO.2

EPNL	AREA (SQ MI)	AREA (SQ KM)
80.0	2.61	6.77
85.0	1.22	3.16
90.0	0.73	1.90
95.0	0.38	0.98
100.0	0.18	0.46

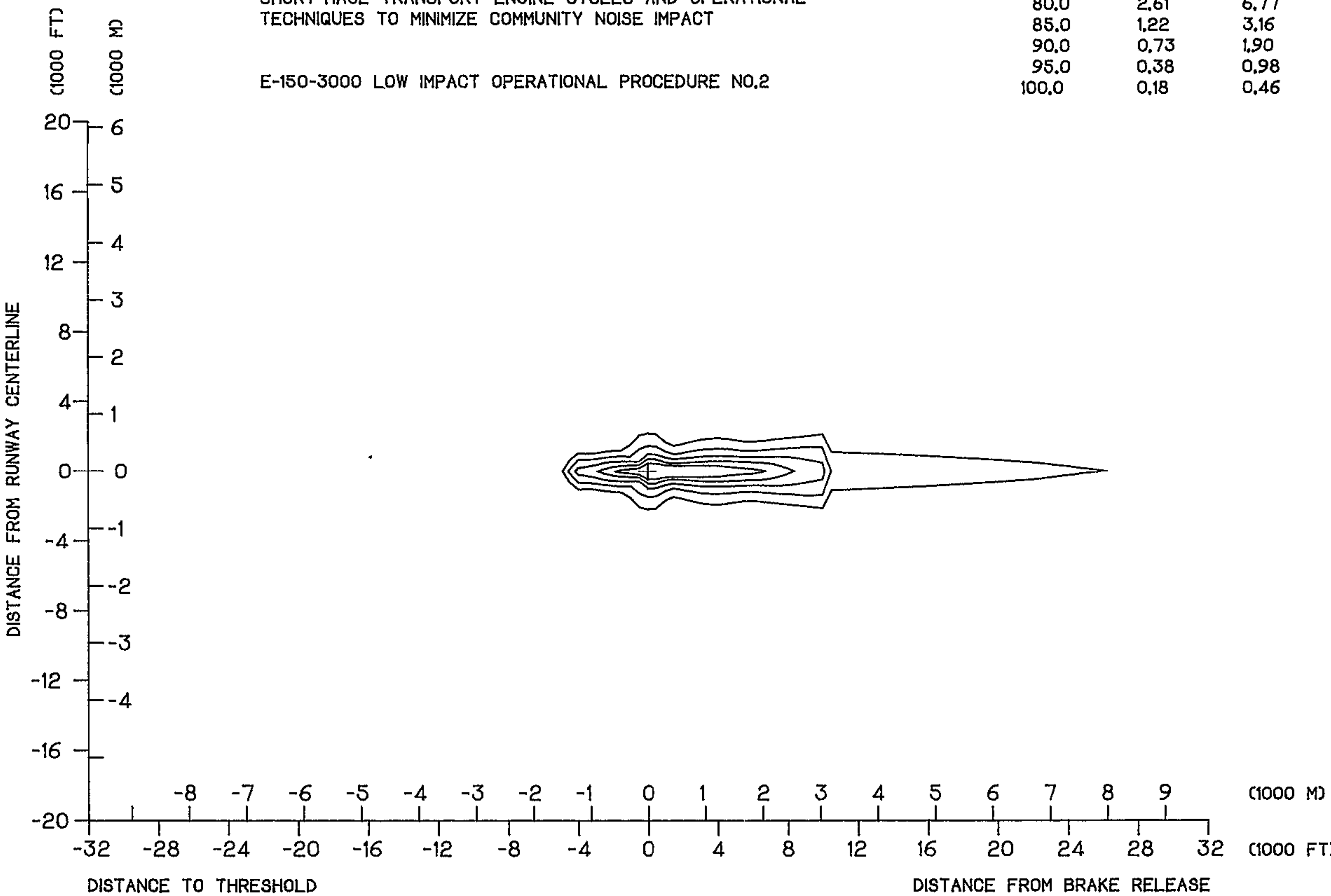


FIGURE 5-38.

NASA AMES CONTRACT -- PARAMETRIC STUDY OF STOL
SHORT-HAUL TRANSPORT ENGINE CYCLES AND OPERATIONAL
TECHNIQUES TO MINIMIZE COMMUNITY NOISE IMPACT

M-150-4000 LOW IMPACT OPERATIONAL PROCEDURE NO. 6

EPNL	AREA (SQ MI)	AREA (SQ KM)
80.0	2.77	7.17
85.0	1.45	3.75
90.0	0.82	2.13
95.0	0.50	1.30
100.0	0.26	0.67

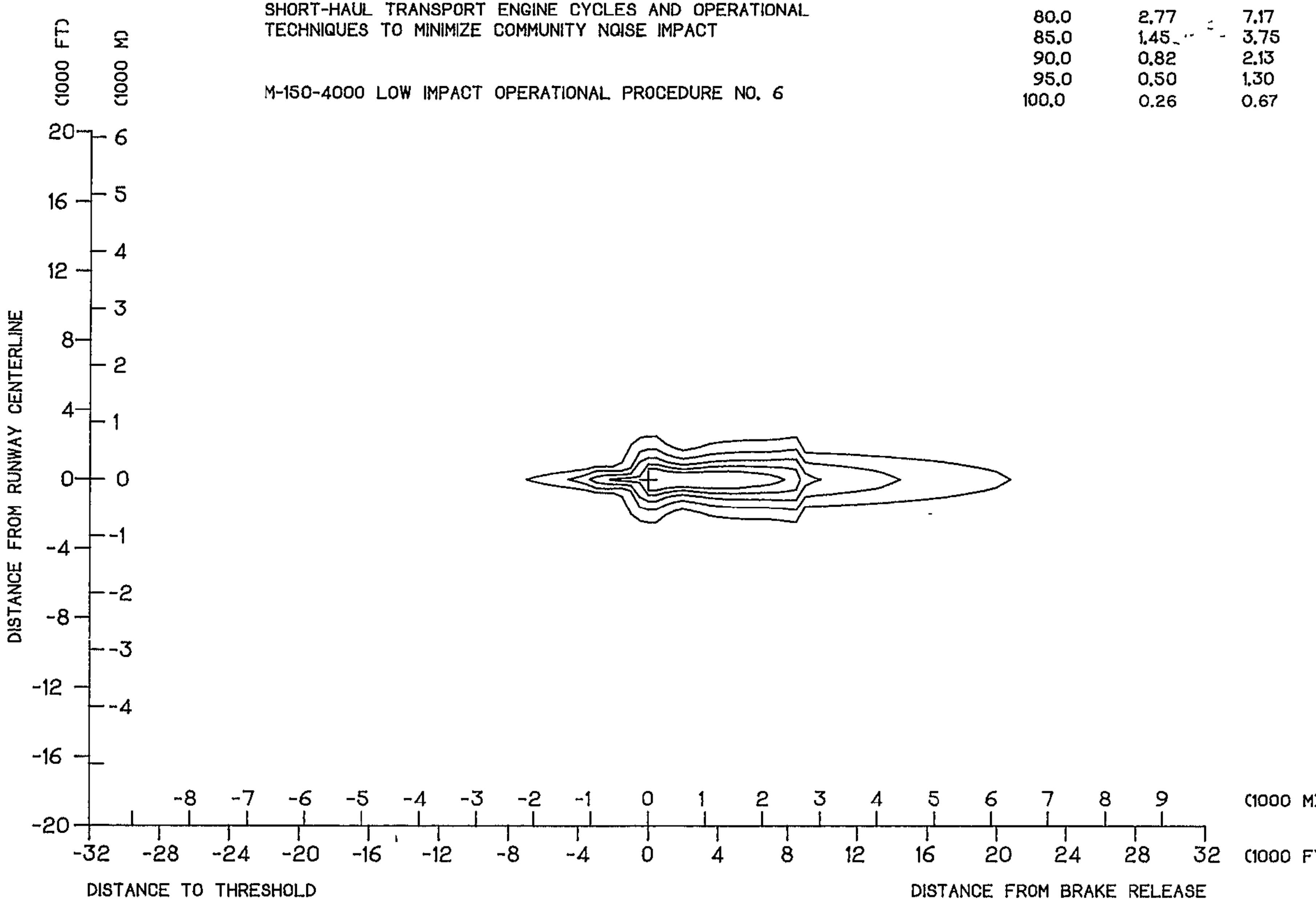


FIGURE 5-39.

optimizing the low-impact approach procedures. For this reason only the takeoff procedures were optimized in Section 5.6 for actual community situations.

5.6 Community Noise Impact Evaluation

The potential for applying the previously described noise abatement operational techniques to a number of representative existing short-haul airports is demonstrated in this section. The four airports selected for this evaluation are well known airports with recognized noise problems. The representative sample includes primary CTOL, secondary CTOL, general aviation and military joint-use airports, each with different community characteristics and noise problems.

5.6.1 Objectives - The primary objective of the airport noise evaluation phase of the study was to demonstrate that aircraft noise impact can be significantly reduced by flight operational techniques. A secondary objective was the development of an effective methodology or tool for assessing aircraft noise impact on the airport and adjacent community. None of the noise evaluation methods now in use fully address the problem of community noise impact. It is hoped this study will provide supporting data for the ultimate development of an industry accepted standard noise prediction and evaluation procedure.

5.6.2 Evaluation Criteria and Procedures - The criterion used for evaluating the aircraft noise impact at a specific airport was the total number of people highly annoyed within the 80 EPNdB contour during a combined takeoff and landing operation. Noise contour area by itself is not an adequate measure of aircraft community noise impact unless the community has a uniform population density. This is rarely the case. Contour areas can be used to compare noise differences between aircraft types and/or operational procedures; however, it is believed essential when measuring community noise impact to determine the number of persons exposed, as well as the degree of annoy-

ance. The methodology which considers these elements for determining the number of people annoyed has been previously described in Section 5.4.1.

Many operational procedures were evaluated at each airport for each aircraft type. A baseline or standard operational procedure was derived using a flight profile developed on the basis of estimated normal operating procedures for short-haul aircraft.

As a result of the parametric study of flight operational techniques of the EBF and MF aircraft a low-impact operational procedure was developed for each aircraft type. The low-impact procedure incorporates the landing and takeoff operational techniques which provided the lowest noise impact assuming a uniform population distribution.

By superimposing the EPNL contours produced by the low-impact operational procedure on a standard 7.5 minute U.S.G.S. topographical map showing population distribution it was possible to optimize or "fine-tune" the low-impact operational procedure and resultant noise contour to the specific airport configuration by varying flight techniques. Primary operational variations were power cutbacks and turns. The contour was shaped by varying the level of power cutback, cutback altitude, and turn amount and altitude. Turns were made where appropriate to follow waterways, railroads, etc., or to avoid highly populated and noise sensitive areas. Optimization was not possible for the landing operational procedure since the area of the noise contours using the low-impact decelerating approach technique already was minimal.

The population data input into the Douglas AIFA computer program was derived from the 1970 census tract and block statistics reports issued by the U.S. Bureau of the Census. In some instances it was found necessary to adjust the block data to reflect areas of zero population (e.g., rivers,

lakes, parks, cemeteries, etc.). The population density was calculated for each 500 foot (152 m) interval grid point over an area of approximately 130 square miles (337 sq. km.).

5.6.3 Airport Selection - A national network of short-haul airports was developed under the previous NASA Short-Haul Systems Study conducted by the Douglas Aircraft Company and reported in Reference 1. A total of over 200 airports were surveyed in the study and twelve representative airports were selected for detailed community analysis. The current study selected four of the twelve for evaluation of noise reduction flight operational techniques. The four airports and their key characteristics are shown in Figure 5-40. All currently are experiencing aircraft noise problems ranging from moderate to severe.

5.6.3.1 Selection Criteria - The earlier NASA Systems Study contained a detailed discussion of the reasons for selection of the twelve airports. Primary criteria were airport type, activity level, geographical location, adjacent land use, and relative importance to a national short-haul transportation system. The four airports evaluated in the current study were chosen as being most representative with respect to operational noise problems and land use characteristics.

5.6.3.2 Airport Characteristics - Operational and community characteristics of the four representative airports are summarized below;

BED - Hanscom Field. Laurence G. Hanscom Field is a joint-use general aviation/military airport located near Bedford, Massachusetts at the western boundary of the Boston metropolitan area. The airport is owned by the Massachusetts Port Authority with a major portion leased to the USAF Electronic Systems Command. The airport and military base encompasses approximately 1125 acres (455 sq. km.). Current operations are almost

AIRPORTS EVALUATED
NOISE REDUCTION OPERATIONAL TECHNIQUES

CODE	AIRPORT	NASP CLASS	OPERATIONAL CLASS.	LAND USE CATEGORY
BED	Hanscom Field Runway 5	S-2	G.A./Military	Residential/Military
DCA	Washington National Runway 18/36	P-2	Air Carrier/G.A.	Recreational/Industrial
SNA	Orange County Runway 19R	S-1	Air Carrier/G.A.	Residential/Commercial
MDW	Chicago Midway Runway 22L Runway 31L	S-2	Air Carrier/G.A.	Residential/Industrial

FIGURE 5-40.

exclusively general aviation, with relatively few military flights. Until recently the field housed some active and reserve Air Force transport aircraft, but these have been relocated. There are no scheduled airline activities at Hanscom at the present time, although the airport is designated as a reliever for Boston-Logan and is classed as an S-2 (Secondary-Medium Density) airport by the FAA.

Runway 5/23 was selected for short-haul operations due to its proximity to the terminal. Runway 5 was selected for noise evaluation as it is more noise sensitive than Runway 23.

The relatively large military base includes some permanent military housing and has an average population density of approximately 370 persons per square mile (140 per sq. km.). Land use in the surrounding communities is predominantly residential but is rural in character. Some light manufacturing is interspersed throughout the area which is fairly wooded. Population density currently is relatively light, averaging approximately 2000 persons per square mile (800 per sq. km.), with higher concentrations in the nearby towns of Bedford, Lexington and Concord. Ambient noise levels of the general area are relatively low. Primary noise sensitive areas are the MIT Lincoln Laboratories which are located on the airport reservation and the Veterans Administration Hospital located north of Bedford. Most aircraft noise complaints originate from the adjacent towns of Lexington and Concord.

<u>DCA - Washington National.</u> Washington National Airport is a major short-haul commercial airport located on the Virginia side of the Potomac River near downtown Washington, D.C. The airport is owned and operated by the Federal Aviation Administration. The field is located on filled land

and encompasses approximately 650 acres (2.63 sq. km.).

DCA is designated as a class P-2 (Primary-Medium Density) airport per NASP classification and handles approximately 5 million passengers annually. Aircraft operations are approximately 70 percent air carrier and 30 percent general aviation. G.A. activities are primarily business jet aircraft. Air carrier operations are predominately short-haul and are currently limited to aircraft of less than 200,000 pounds (90,720 kg.) takeoff gross weight (B727 and smaller).

Runway 18/36 is the primary air carrier runway with operations approximately 50 percent in each direction. Runway 36 was selected for noise evaluation as it is the most critical with respect to community impact. Stringent noise abatement flight procedures are currently in effect at DCA. ATC procedures primarily direct flights over the Potomac River and away from populated areas. Flights over government centers are prohibited.

Land use in the immediate airport vicinity is primarily recreational and includes boating marinas, landscaped parkways, and a waterfowl santuary. Arlington National Cemetary, Ft. Meyer, and the Pentagon are located to the north and west of the airport. A major railroad marshalling yard is located south and west of the airport. The city of Alexandria is located south of the airport and the central and Georgetown areas of Washington, D.C. are to the north.

Population density in the vicinity of Alexandria is approximately 12,000 persons per square mile (4600 per sq. km.) and in the D.C. and Georgetown areas is approximately 20,000 persons per square mile (8500 per sq. km.). The entire area is highly urbanized and ambient noise levels are

relatively high due to automobile traffic and other concentrated urban activities.

SNA - Orange County Airport. Orange County Airport is located in the southern coastal region of the Los Angeles basin and serves the rapidly growing South Bay area. The county-owned airport is located near the cities of Newport Beach, Costa Mesa and Santa Ana. The airport is relatively small in area, encompassing only 520 acres (2.1 sq. km.) but is one of the nation's most active and controversial airports. The airport serves both short-haul air carrier and general aviation operations and is a major reliever of LAX traffic. SNA is rated as an S-1 (Secondary-High Density) airport according to the 1972 NASP classification. In 1973 the level of aircraft operations increased to over 630,000 making it the second busiest airport in the nation. Air carrier operations, however, accounted for less than 1 percent of the total.

The primary runway OIL/19R is the only runway capable of jet operations. Due to prevailing wind conditions, runway 19R is used over 95 percent of the time. This runway also is the most noise sensitive and therefore was selected for the subject noise evaluation. Rigid noise abatement procedures are in effect and permanent noise monitoring equipment is installed.

Land use in the adjacent communities is predominantly residential, however, the areas to the north and east include both military and industrial facilities. The area to the north is sparsely populated but is fast becoming urbanized. The communities of Costa Mesa to the west, and Newport Beach to the south already are highly urbanized, with high value residential properties

directly under the takeoff flight paths. Average value of homes within the noise-impacted Newport Beach area is in excess of $50,000 according to the 1970 census. The University of California at Irvine is located just southeast of the airport. Population density in the Newport Beach area is approximately 9000 persons per square mile (3500 persons per sq. km.). Since the area is predominantly high-value residential, ambient noise levels are relatively low and accentuate the aircraft noise problem.

Accordingly, Orange County Airport in addition to being one of the nation's busiest airports also is one of the most noise sensitive.

MDW - Midway Airport. Chicago's Midway Airport, located in the Cicero section of South Chicago, is one of the nation's earliest air carrier airports. Dedicated in 1927, but relatively inactive since the opening of O'Hare International in 1960, the airport recently has been actively promoted as a reliever for O'Hare's short-haul traffic. Air carrier activity currently is relatively light and the airport is highly under-utilized. Midway is owned by the City of Chicago and managed by the Chicago Department of Aviation. The airport encompasses approximately 640 acres (2.6 sq. km.) and is bordered by residential areas on all four sides. As the airport was built prior to the advent of all-weather operations there are no clear zones extending beyond the field boundary.

Midway was rated as a Class S-2 (Secondary-Medium Density) airport in the 1972 National Airport Systems Plan and handled slightly over one million total passengers annually. Air carrier operations currently account for less than 10 percent of the total operations, the remainder being predominently general aviation with some military reserve activity.

Runways 4R/22L and 13R/31L are the primary air carrier runways. Due to prevailing wind conditions, runways 22L and 31L are the predominant use runways and were accordingly selected for noise evaluation. The majority of noise complaints originate from operations on runway 31L. Departures from runways 22L and 31L are split approximately 60 percent to the west and 40 percent to the east. Departure turns are made to the right or left on either runway but are held to within a 3 mile (4.8 km.) radius of the field to avoid conflict with O'Hare traffic. Midway traffic is closely coordinated with O'Hare operations and approaches and departures normally use runway directions similar to those at O'Hare. There are no special noise abatement procedures in effect at Midway at the present time.

Land use in the immediate vicinity of Midway is predominantly residential with single dwelling housing extending up to the city streets bordering the mile square airport area. Approximately twenty-two schools are located within a two mile (3.2 km.) radius of the airport. An industrial corridor parallels the Southwest Expressway approximately one mile (1.6 km.) north of the airport. The Chicago sanitary and ship canal and the Santa Fe tracks also follow this corridor which extends in a southwesternly direction The corridor widens into a major industrial area approximately 3 miles (5 km.) west of the airport near the Des Plaines river. A second large industrial area is located approximately one-half mile (.8 km.) south of the airport. This area in the Bedford Park Section of Chicago includes a major rail marshalling yard, extensive factories, and other industrial facilities. The area to the east of the airport is mostly single story residential. Population density of the residential areas in the immediate vicinity of the airport is approximately 15,000 persons per square mile

(5800 persons per sq. km.). Population density increases to approximately 40,000 persons per square mile (15,500 persons per sq. km.) in the Englewood section, approximately 5 miles (8 km.) east of the airport. Maximum population density in the survey area is 54,000 persons per square mile (21,000 persons per sq. km.) in the high-rise apartment areas near Douglas Park, approximately 6 miles (10 km.) northeast of Midway Airport.

Ambient noise levels in the immediate vicinity of Midway are relatively high due to the high degree of urbanization and related surface vehicular traffic. This may account for the relatively small number of noise complaints experienced at Midway.

5.6.4 Community Noise Impact - EBF Airplane - Aircraft characteristics and noise reduction flight operational techniques applicable to the E-150-3000 airplane were previously discussed in Sections 5.2 and 5.5. The following describes the results of applying these techniques at the four study airports. Landing and takeoff flight profiles and noise footprint maps are shown for the E-150-3000 standard, low-impact, and minimum-impact procedures at each airport. The low-impact flight procedures and resultant noise contours were developed from the operational parametric analysis which assumed a uniform population distribution. The standard and low-impact flight procedures therefore are the same at all airports. The minimum-impact procedure was developed by "fine-tuning" the flight procedures to specific airport and community characteristics and differs at each airport.

The landing procedure for the E-150-3000 minimum-impact profile also is identical to that of the low-impact landing flight profile since the low-impact approach procedure developed in the acoustic parametric study represents the optimum within acceptable limits of flight safety. Accordingly, the resultant landing condition noise footprints for both the low-impact and minimum-impact cases are identical for all airports and runway combinations.

The standard takeoff and landing flight profiles of the E-150-3000 airplane were previously shown in Figures 5-16 and 5-20. The low-impact landing and takeoff flight profiles of the E-150-3000 airplane were shown in Figures 5-34 and 5-35.

Single-event noise contours for 100, 95, 90, 85, and 80 EPNdB levels were developed for each flight procedure. The NASA Systems Study

(Reference 1) did not evaluate noise levels below 90 EPNdB. It was found during the current study that a significant number of people are affected within the contour bands between 80 and 90 EPNdB which justifies investigation of the lower noise level. The single-event noise level of 80 EPNdB for the two aircraft analyzed translates to approximately 67 dBA which is below the ambient noise level of most urban communities.

5.6.4.1 Noise Impact - HANSCOM FIELD - The community noise impact evaluation of the standard, low-impact, and minimum-impact flight procedures of the E-150-3000 airplane at Hanscom Field Runway 5 is summarized below.

Standard Procedure. The single-event landing and takeoff noise footprints resulting from the standard or baseline operational techniques are shown in Figure 5-41. As shown, the 100 EPNdB footprint is almost entirely contained within the airport boundary. The 90 EPNdB footprint, which is normally considered the complaint threshold, also is more than 50 percent airport contained. The 85 and 80 EPNdB footprints project into the town of Bedford with the 80 EPNdB spike extending to the Massachusetts Turnpike, approximately 3 miles (4.8 km) from the airport.

Low-Impact Procedure. The single-event noise footprints using the low-impact flight procedure are shown in Figure 5-42. The power cutback used in this technique shortened the 90 and 85 EPNdB takeoff lobes reducing their impact on Bedford. The 80 EPNdB takeoff spike however was lengthened approximately 1 mile (1.6 km) due to the reduced climb gradient after thrust cutback.

NOISE FOOTPRINTS — STANDARD FLIGHT PROCEDURE
HANSCOM FIELD, RWY 5 — E·150·3000 AIRPLANE

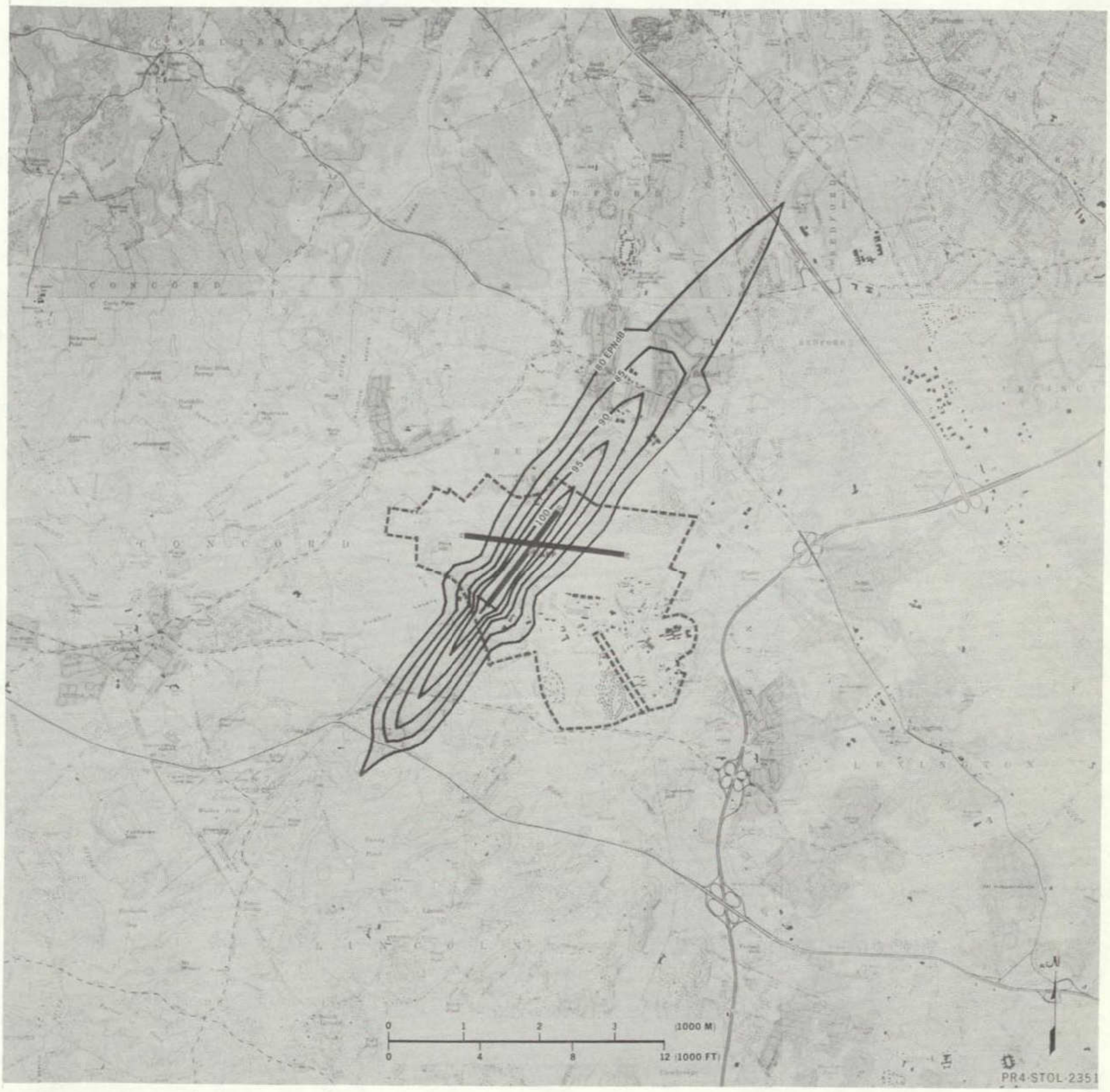


FIGURE 5-41.

NOISE FOOTPRINTS — LOW IMPACT PROCEDURE
HANSCOM FIELD, RWY 5 — E·150·3000 AIRPLANE

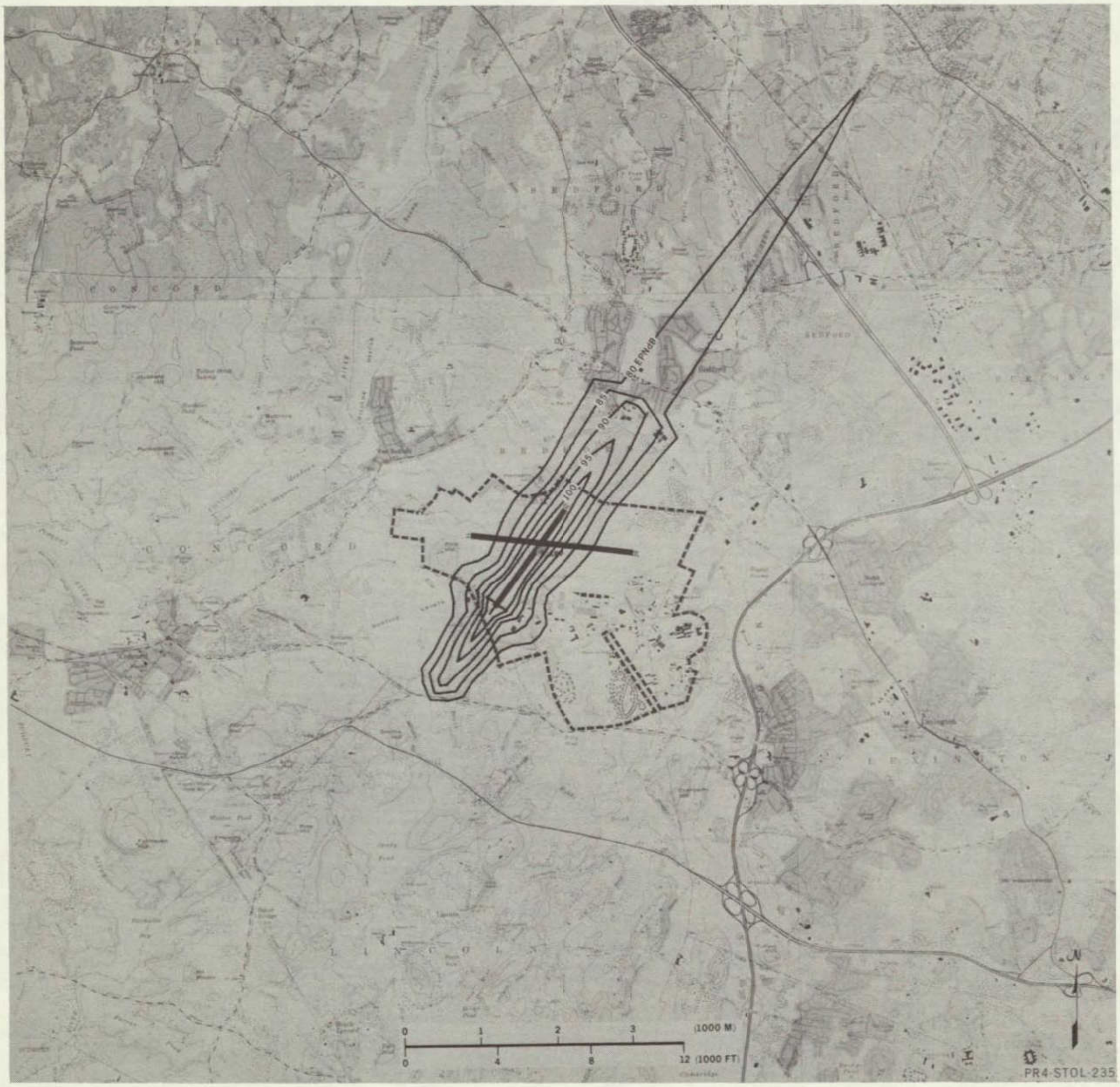


FIGURE 5-42.

Minimum-Impact Procedure. The minimum-impact flight procedure represents the best of eight different techniques investigated. Primary perturbations were variations in power cutback amount and cutback altitude. Although the previous study of Reference 1 showed a curvilinear takeoff path at Hanscom, examination of the census population distribution indicated a straight flight path was most effective in reducing population impact. A takeoff power cutback to 64 percent gross takeoff thrust at an altitude of 800 feet (244 m), as shown in Figure 5-43, provided the minimum community impact. The resultant single-event noise footprints are shown in Figure 5-44. As noted, the 90 EPNdB lobe falls short of the town of Bedford and the 85 EPNdB lobe projects only slightly into the urbanized section of the town. The 80 EPNdB takeoff spike however is lengthened due to the reduced climb gradient and extends approximately 5 miles (8 km) up the Shawsheen River almost to the town of Pinehurst. This area is relatively unpopulated. Only one school is impacted by the 80 EPNdB footprint of the minimum-impact procedure.

A summary of the community impact of the above flight procedures is presented in Table 5-5. Both the total population affected and the number of persons highly annoyed are shown. The low-impact procedure provided a 36 percent reduction in persons highly annoyed and the minimum-impact procedure provided a slightly greater reduction of 37 percent. The minimum-impact procedure, however, resulted in 224 additional persons exposed to the 80 EPNdB footprint compared to the low-impact procedure.

5.6.4.2 Noise Impact - WASHINGTON NATIONAL - The community noise impact evaluation of the E-150-3000 airplane at Washington National Runway 36 is summarized below. Results of the standard flight technique using Runway 18

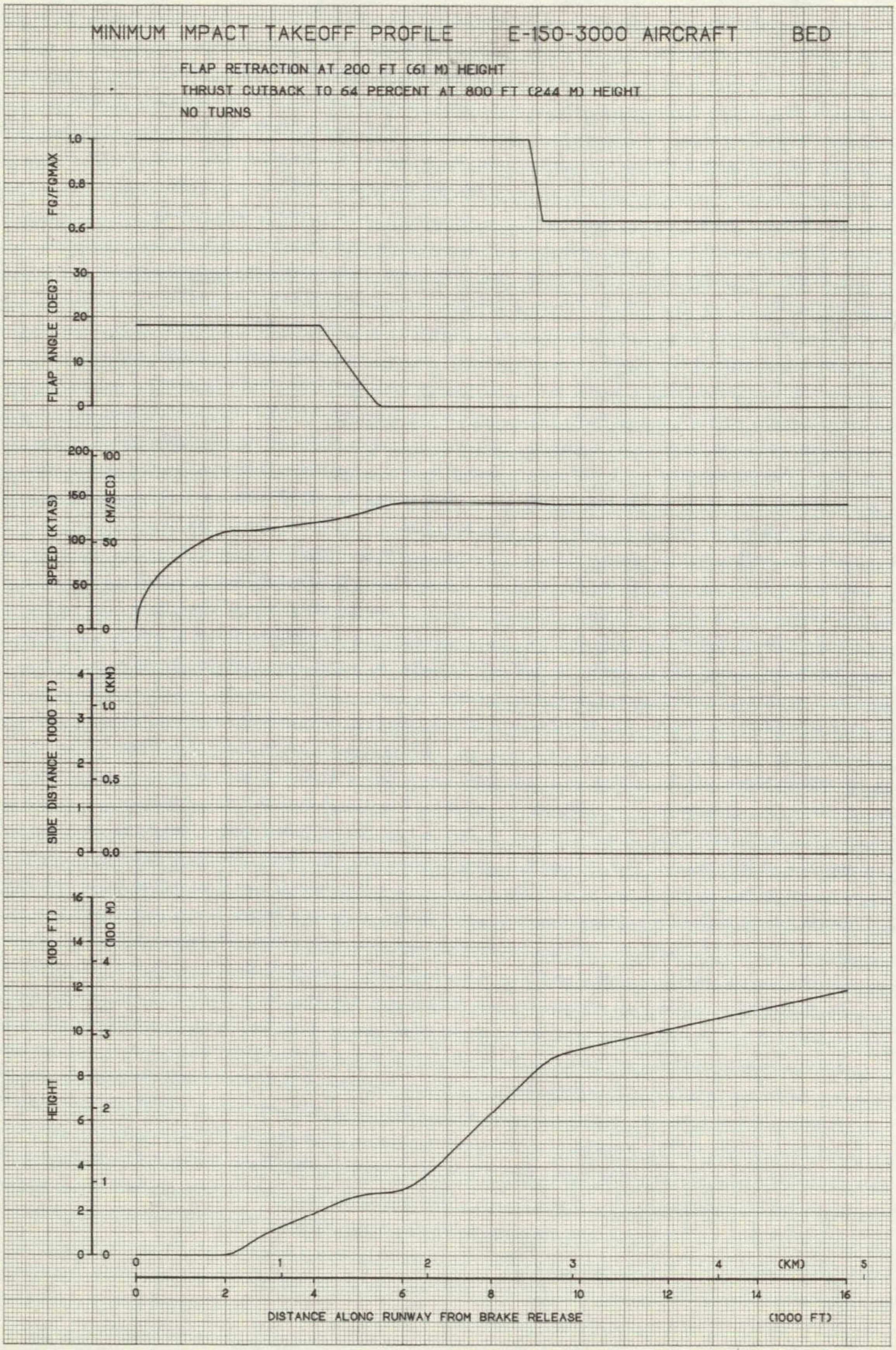

MINIMUM IMPACT TAKEOFF PROFILE E-150-3000 AIRCRAFT BED
FLAP RETRACTION AT 200 FT (61 M) HEIGHT
THRUST CUTBACK TO 64 PERCENT AT 800 FT (244 M) HEIGHT
NO TURNS
FG/FGMAX
FLAP ANGLE (DEG)
SPEED (KTAS)
(M/SEC)
SIDE DISTANCE (1000 FT)
(KM)
HEIGHT (100 FT)
(100 M)
(KM)
DISTANCE ALONG RUNWAY FROM BRAKE RELEASE
(1000 FT)

FIGURE 5-43.

NOISE FOOTPRINTS — MINIMUM IMPACT PROCEDURE
HANSCOM FIELD, RWY 5 — E·150·3000 AIRPLANE

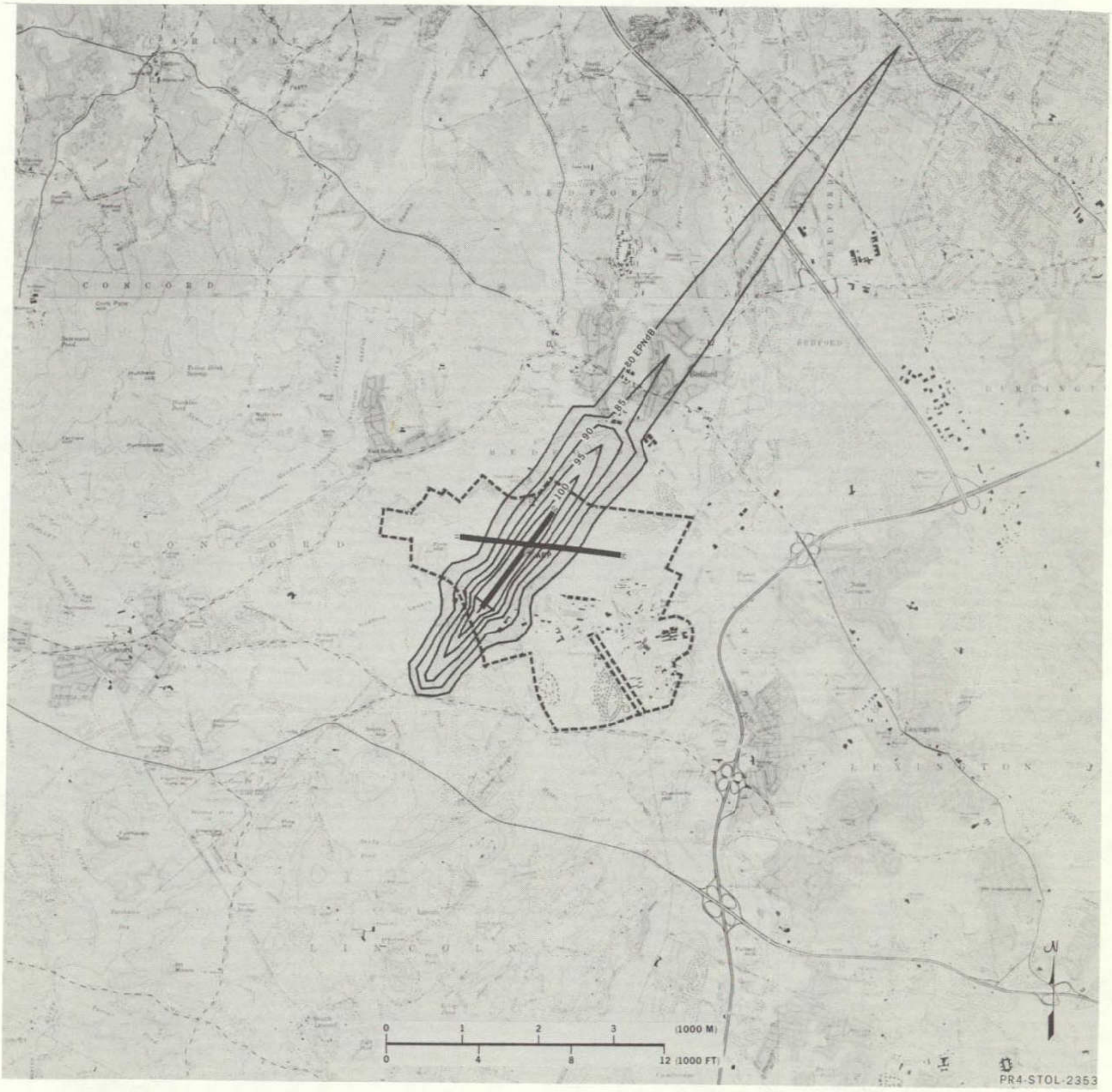


FIGURE 5-44.

TABLE 5-5

NOISE IMPACT SUMMARY - E.150.3000 AIRPLANE

HANSCOM FIELD - RUNWAY 5

	STANDARD PROCEDURE				LOW-IMPACT PROCEDURE				MINIMUM-IMPACT PROCEDURE			
EPNL	Contour Area		Population		Contour Area		Population		Contour Area		Population	
Contour	Sq.Mi.	Sq.Km.	Affected	Annoyed	Sq.Mi.	Sq.Km.	Affected	Annoyed	Sq.Mi.	Sq.Km.	Affected	Annoyed
100	0.18	0.45	56	27	0.18	0.46	53	26	0.18	0.46	53	26
95	0.44	1.14	142	57	0.38	0.98	117	48	0.38	0.98	117	48
90	0.92	2.38	427	125	0.73	1.90	322	99	0.69	1.79	261	85
85	1.71	4.43	1122	230	1.22	3.16	616	141	1.18	3.07	564	124
80	3.19	8.27	2682	297	2.61	6.77	1855	190	2.84	7.37	2079	188

also are presented due to the high usage of this less noise sensitive runway.

Standard Procedure. The single-event landing and takeoff noise footprints using the standard procedure for a north arrival and departure on Runway 36 are shown in Figure 5-45. The 100 and 95 EPNdB footprint are essentially contained within the airport boundary. The major portion of the 90 and 85 EPNdB footprints extend over the Potomac River with some land impact along unpopulated areas of the river bank. The 80 EPNdB footprint of the straight departure path extends across Constitution Avenue into the downtown section of D.C. just west of the White House.

Low-Impact Procedure. The single event noise footprints using the low-impact procedure are shown in Figure 5-46. The power cutback used in this procedure shortened the 90 and 85 EPNdB takeoff lobes but extended the 80 EPNdB spike approximately 1 mile (1.6 km) into the downtown D.C. area to a point slightly beyond DuPont Circle.

Minimum-Impact Procedure. A total of seven different takeoff maneuvers were evaluated in developing the minimum-impact procedure. A turning takeoff flight path was used in developing the minimum-impact footprint shown in Figure 5-47. The corresponding takeoff flight profile is shown in Figure 5-48. A 30 degree (.524 radian) left turn initiated at 500 feet (152 m) with a power cutback to 64 percent maximum gross takeoff thrust at 1275 feet (389 m) on completion of the turn resulted in zero population impact. As shown, the resultant flight path extends up the Potomac River with the 80 EPNdB footprint spike terminating near the Roosevelt Memorial on Theodore Roosevelt Island.

NOISE FOOTPRINTS - STANDARD FLIGHT PROCEDURE
WASHINGTON NATIONAL, RWY 36 — E·150·3000 AIRPLANE

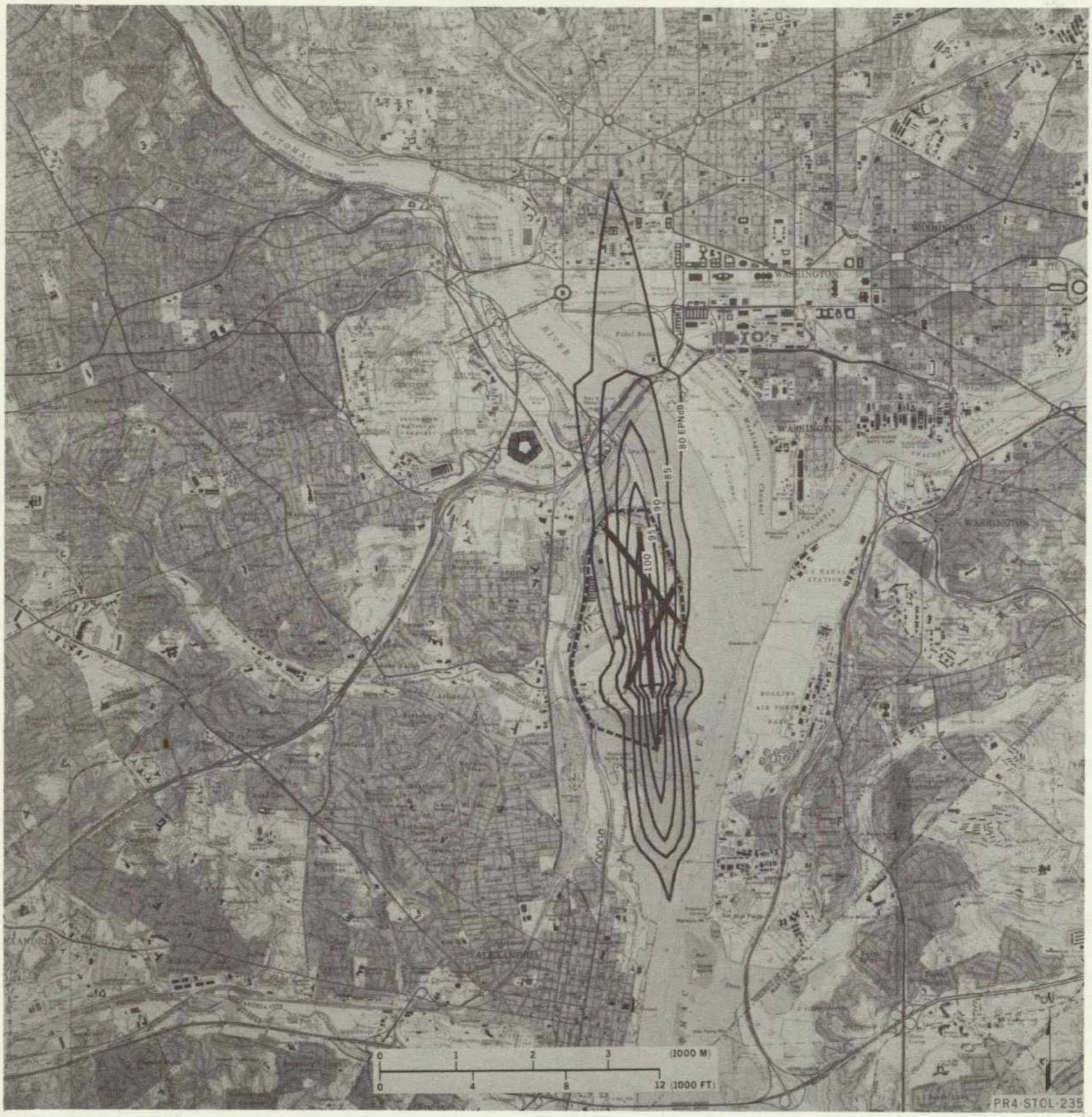


FIGURE 5-45.

NOISE FOOTPRINTS – LOW-IMPACT PROCEDURE
WASHINGTON NATIONAL, RWY 36 – E·150·3000 AIRPLANE

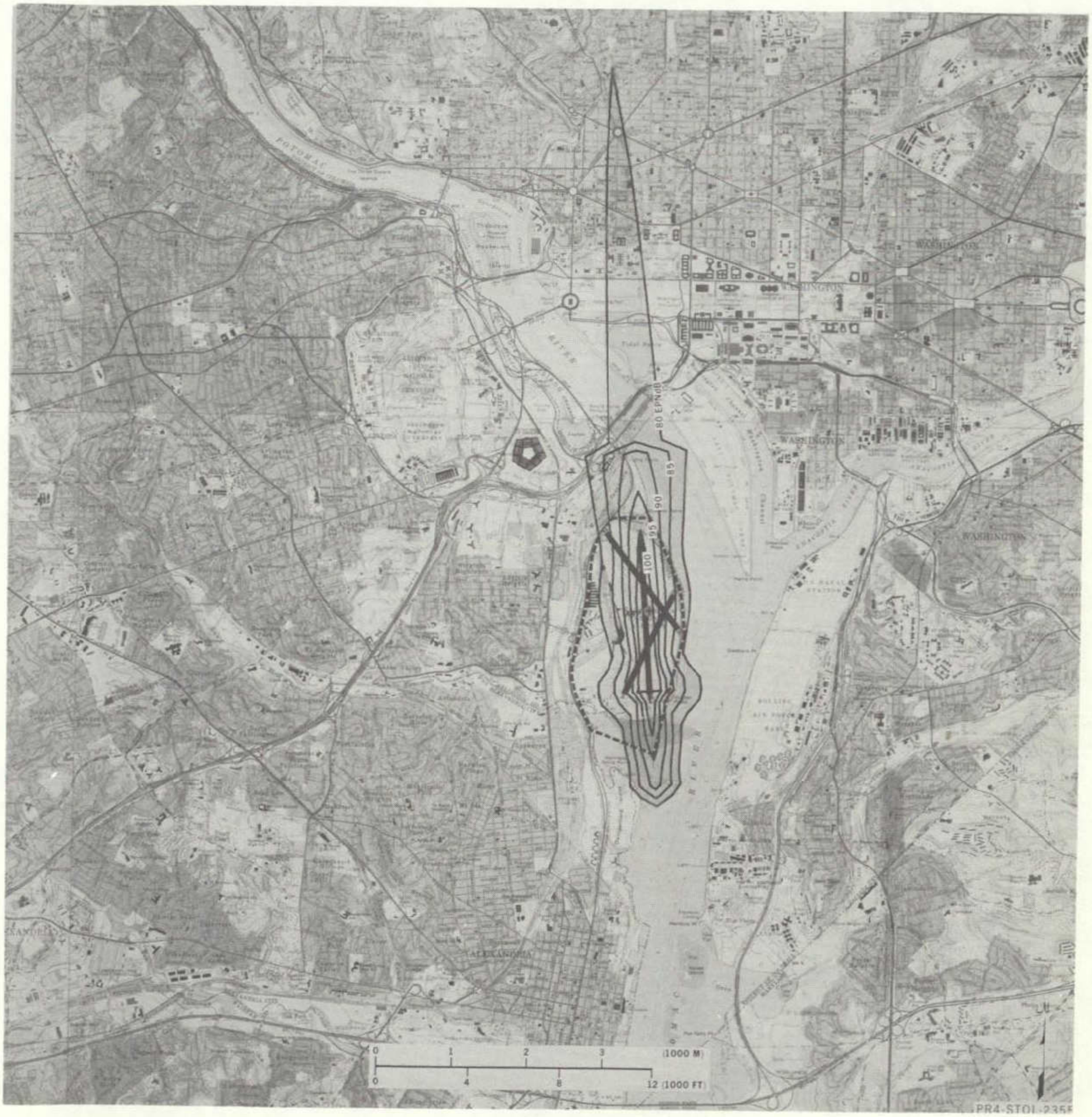


FIGURE 5-46.

NOISE FOOTPRINTS — MINIMUM IMPACT PROCEDURE
WASHINGTON NATIONAL, RWY 36 — E·150·3000 AIRPLANE

FIGURE 5-47.

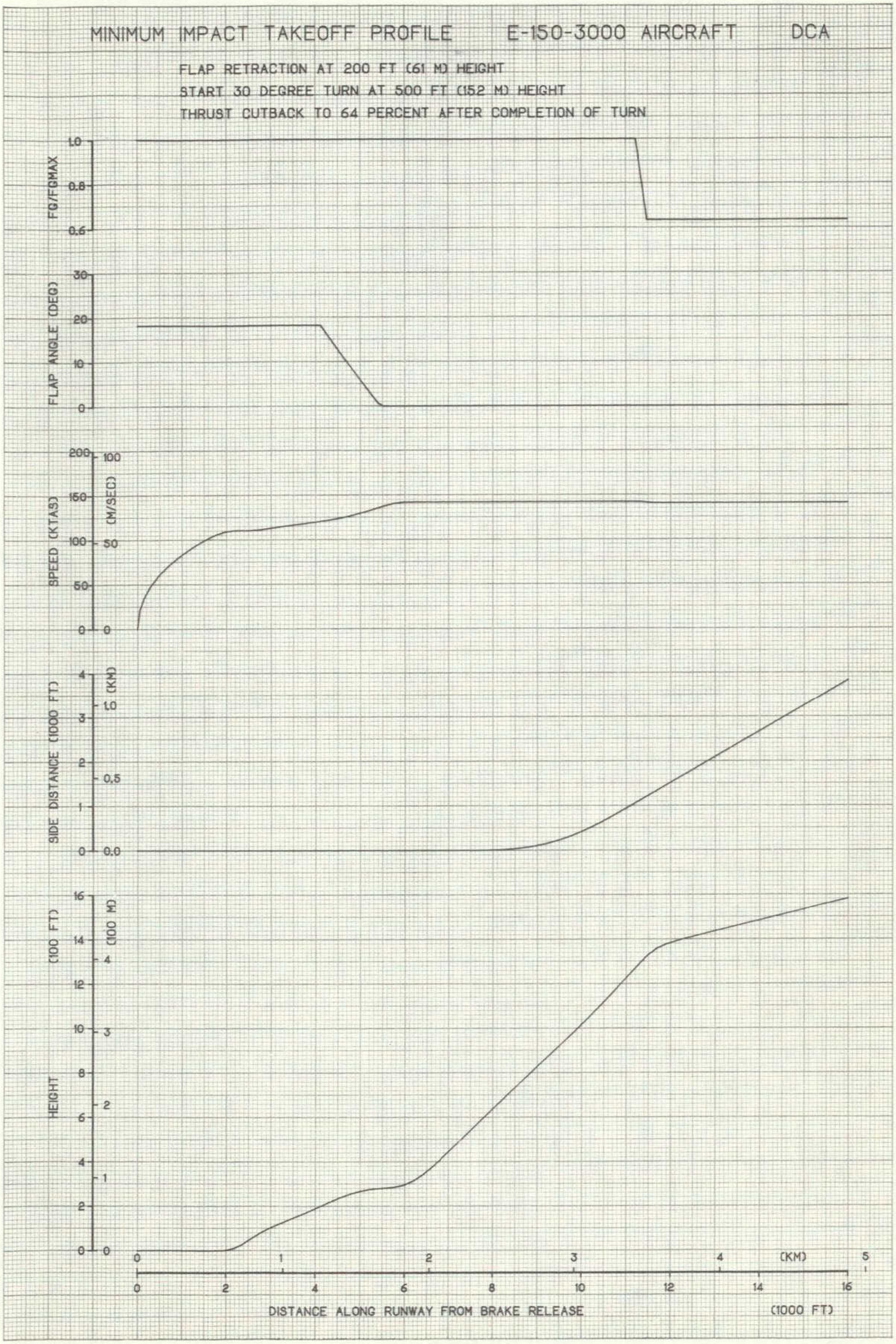

MINIMUM IMPACT TAKEOFF PROFILE E-150-3000 AIRCRAFT DCA
FLAP RETRACTION AT 200 FT (61 M) HEIGHT
START 30 DEGREE TURN AT 500 FT (152 M) HEIGHT
THRUST CUTBACK TO 64 PERCENT AFTER COMPLETION OF TURN
FG/FGMAX
FLAP ANGLE (DEG)
SPEED (KTAS)
(M/SEC)
SIDE DISTANCE (1000 FT)
(KM)
HEIGHT
(100 FT)
(100 M)
(KM)
DISTANCE ALONG RUNWAY FROM BRAKE RELEASE
(1000 FT)

FIGURE 5-48.

Standard Flight Procedure - Runway 18. The standard flight procedure also was examined using a south arrival and departure on Washington National Runway 18 as shown in Figure 5-49. The 80 EPNdB footprint of the straight departure path extends over the Potomac River and impacts only a small unpopulated section of the river bank on the Virginia side. Since the population impact of the standard procedure was zero, evaluation of additional operational techniques for this runway was considered unnecessary.

The results of the community impact evaluation of the E-150-3000 at Washington National Airport are summarized in Table 5-6. It should be noted that the population impact of the low-impact procedure on Runway 36 was greater than that of the standard procedure. The increase from the standard procedure resulted from a lower power cutback height which extended the 80 and 85 EPNdB contours over highly populated areas. The minimum-impact procedure for Runway 36 resulted in zero impact, as did the standard flight procedure on Runway 18.

5.6.4.3 Noise Impact - ORANGE COUNTY AIRPORT - The community noise impact evaluation of the standard, low-impact, and minimum-impact flight procedures of the E-150-3000 airplane at Orange County Airport, Runway 19R is summarized below.

Standard Procedure. The single-event landing and takeoff noise footprints using the standard flight procedure are shown in Figure 5-50. The 100 and the 95 EPNdB footprints are essentially contained within the airport boundary, with the 90 and 85 EPNdB takeoff and sideline lobes extending slightly into residential areas adjacent to the southern boundaries of the airport. The 80 EPNdB takeoff lobe of the straight departure path extends into highly

NOISE FOOTPRINTS — STANDARD FLIGHT PROCEDURE
WASHINGTON NATIONAL, RWY 18 — E·150·3000 AIRPLANE

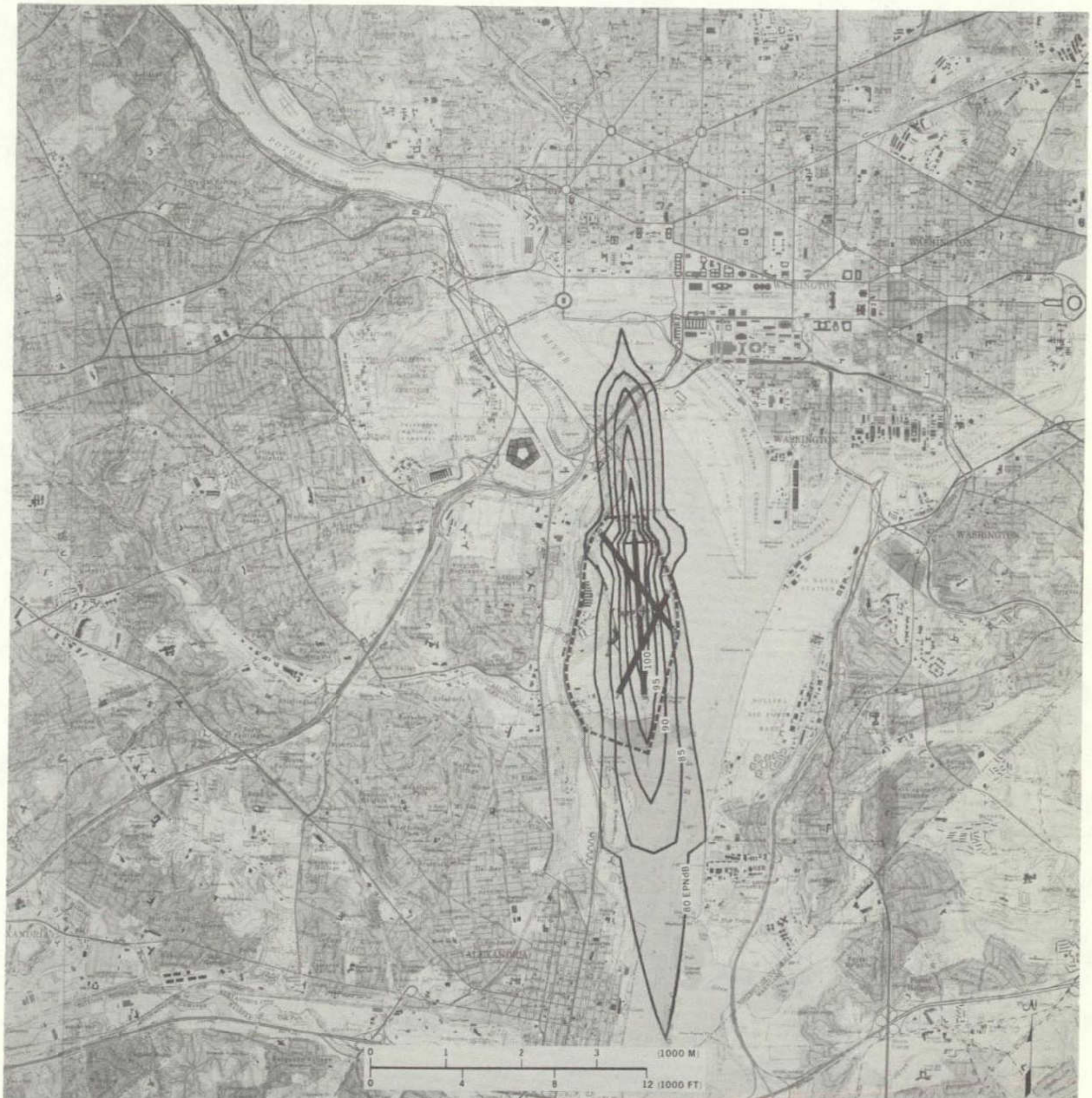


FIGURE 5-49.

Table 5-6

NOISE IMPACT SUMMARY - E.150.3000 AIRPLANE

WASHINGTON NATIONAL - RUNWAY 36*

EPNL	STANDARD PROCEDURE				LOW IMPACT-PROCEDURE				MINIMUM-IMPACT PROCEDURE			
	Contour Area		Population		Contour Area		Population		Contour Area		Population	
Contour	Sq.Mi.	Sq.Km.	Affected	Annoyed	Sq.Mi.	Sq.Km.	Affected	Annoyed	Sq.Mi.	Sq.Km.	Affected	Annoyed
100	0.18	0.45	0	0	0.18	0.46	0	0	0.18	0.46	0	0
95	0.44	1.14	0	0	0.38	0.98	0	0	0.38	0.98	0	0
90	0.92	2.38	0	0	0.73	1.90	0	0	0.75	1.95	0	0
85	1.71	4.43	0	0	1.22	3.16	0	0	1.39	3.61	0	0
80	3.19	8.27	649	9	2.61	6.77	3116	30	2.42	6.26	0	0

* NOTE: Population affected and/or annoyed is zero for all three above flight procedures when operating from Runway 18.

NOISE FOOTPRINTS — STANDARD FLIGHT PROCEDURE
ORANGE COUNTY AIRPORT, RWY 19R — E•150•3000 AIRPLANE

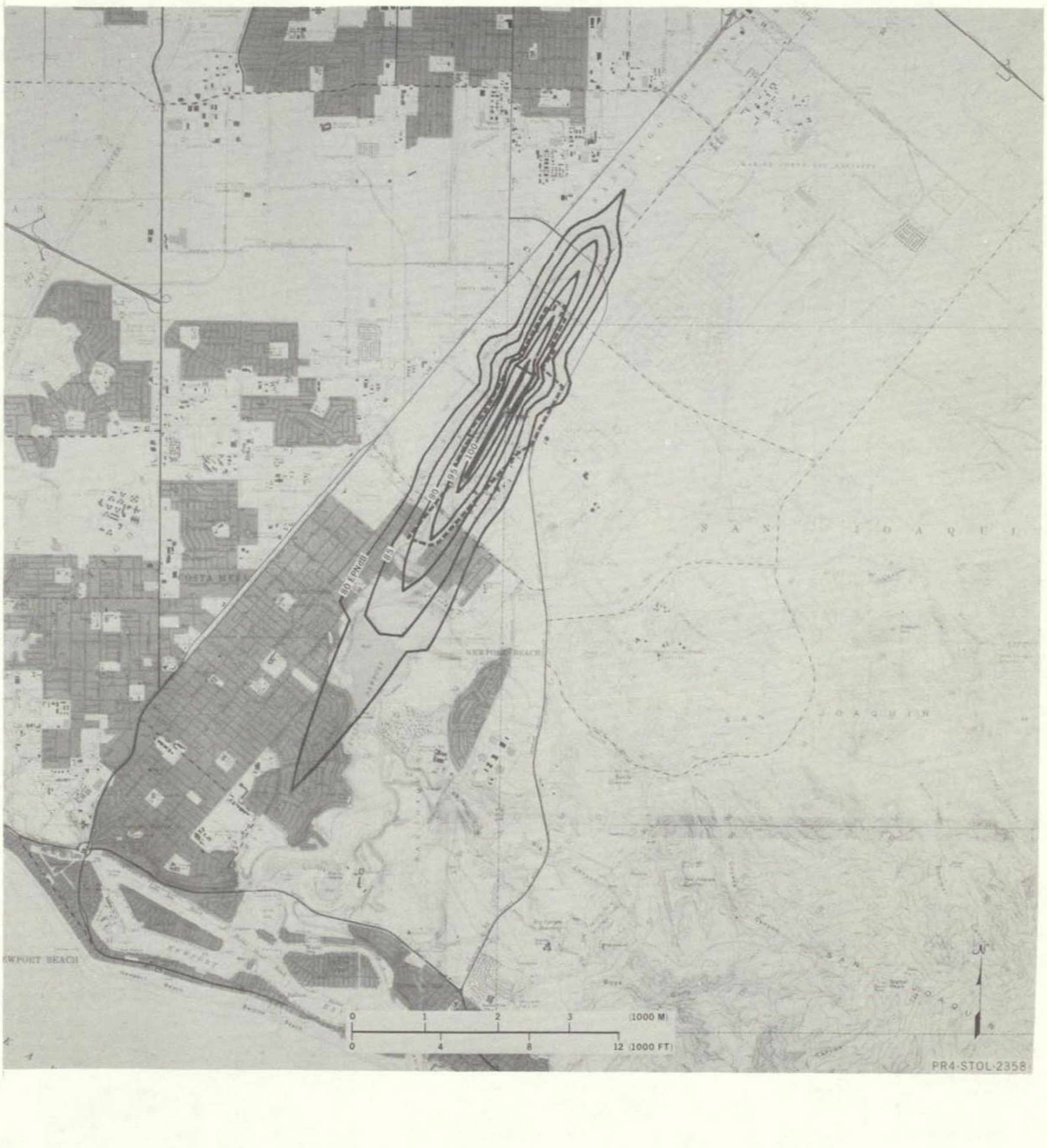


FIGURE 5-50.

noise sensitive residential areas around Upper Newport Bay, although a major portion impacts upon the Bay itself.

Low-Impact Procedure. The single event noise footprints using the low-impact procedure are shown in Figure 5-51. The power cutback with this procedure reduced the impact of the sideline noise but increased the impact of the 80 EPNdB takeoff spike which extends approximately 3 miles (4.8 km) southward to the Coast Highway.

Minimum-Impact Procedure. A total of twelve flight procedures were evaluated. The takeoff procedure which produced the lowest impact is presented in Figure 5-52. The minimum-impact procedure involved a power cutback to 66 percent gross takeoff thrust initiated at 750 feet (229 m) altitude followed by a 20 degree (.349 radian) turn to the left initiated at 850 feet (259 m) altitude followed by a power reduction to 64 percent thrust. The resultant minimum-impact noise footprint is shown in Figure 5-53. The flight path parallels the centerline of Upper Newport Bay. The early power cutback significantly decreases the sideline noise impact near the field boundary. The 80 EPNdB takeoff spike extends over a populated area in the East Bluff section of the City of Newport Beach and slightly into Balboa Island, however, no schools are located within the minimum-impact footprint. Shortening the 80 EPNdB spike increased the sideline impact in the Upper Newport Bay area and resulted in greater total impact. A power variation technique, as shown in Figure 5-54 was tried in an attempt to reduce the sideline noise impact but also resulted in an increase in overall noise impact. The noise footprints of the above power variation technique shown in Figure 5-55 are shown to illustrate the effect of power variations on the sideline noise contours.

NOISE FOOTPRINTS — LOW IMPACT PROCEDURE
ORANGE COUNTY AIRPORT RWY 19R — E·150·3000 AIRPLANE

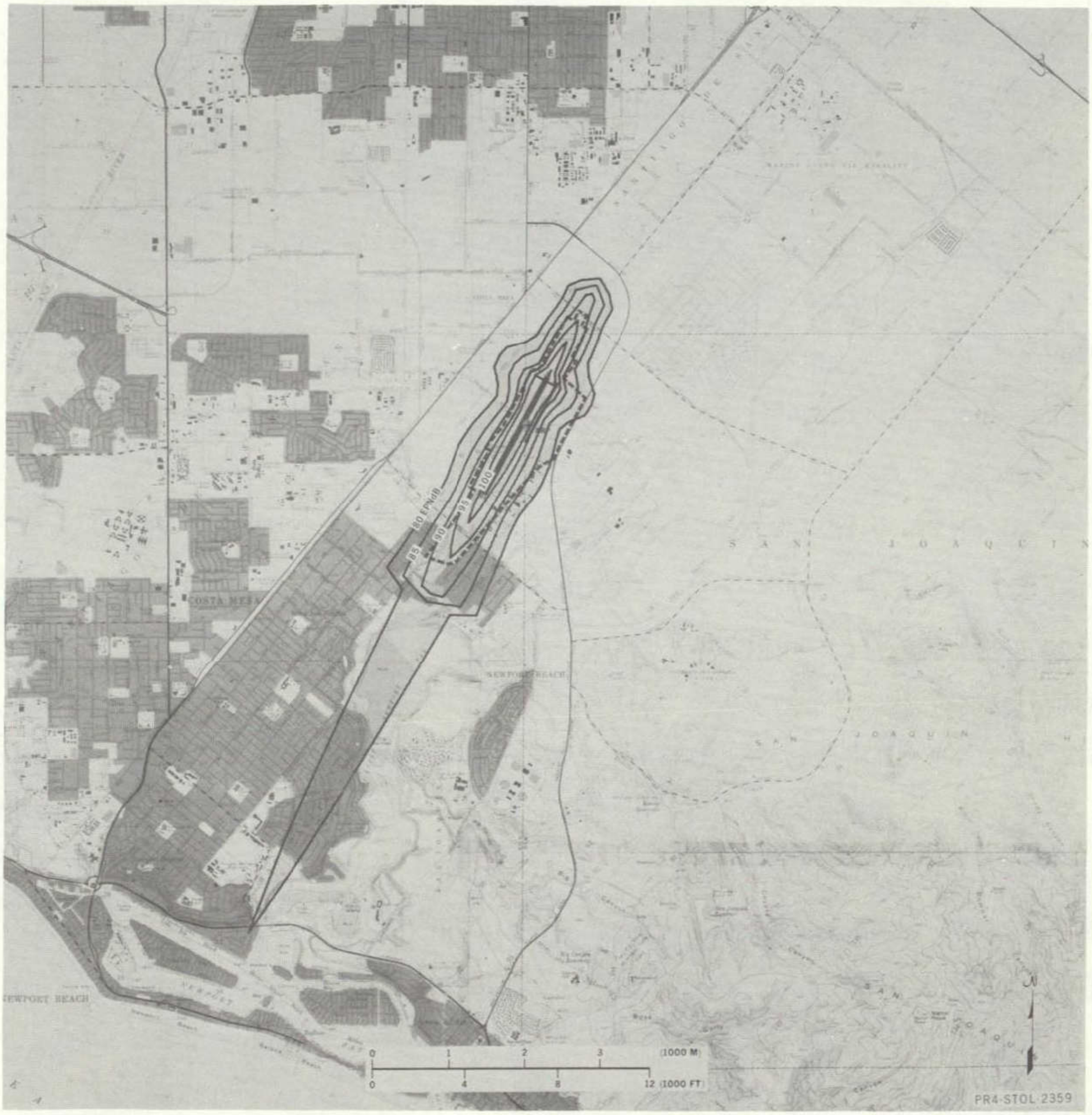


FIGURE 5-51.

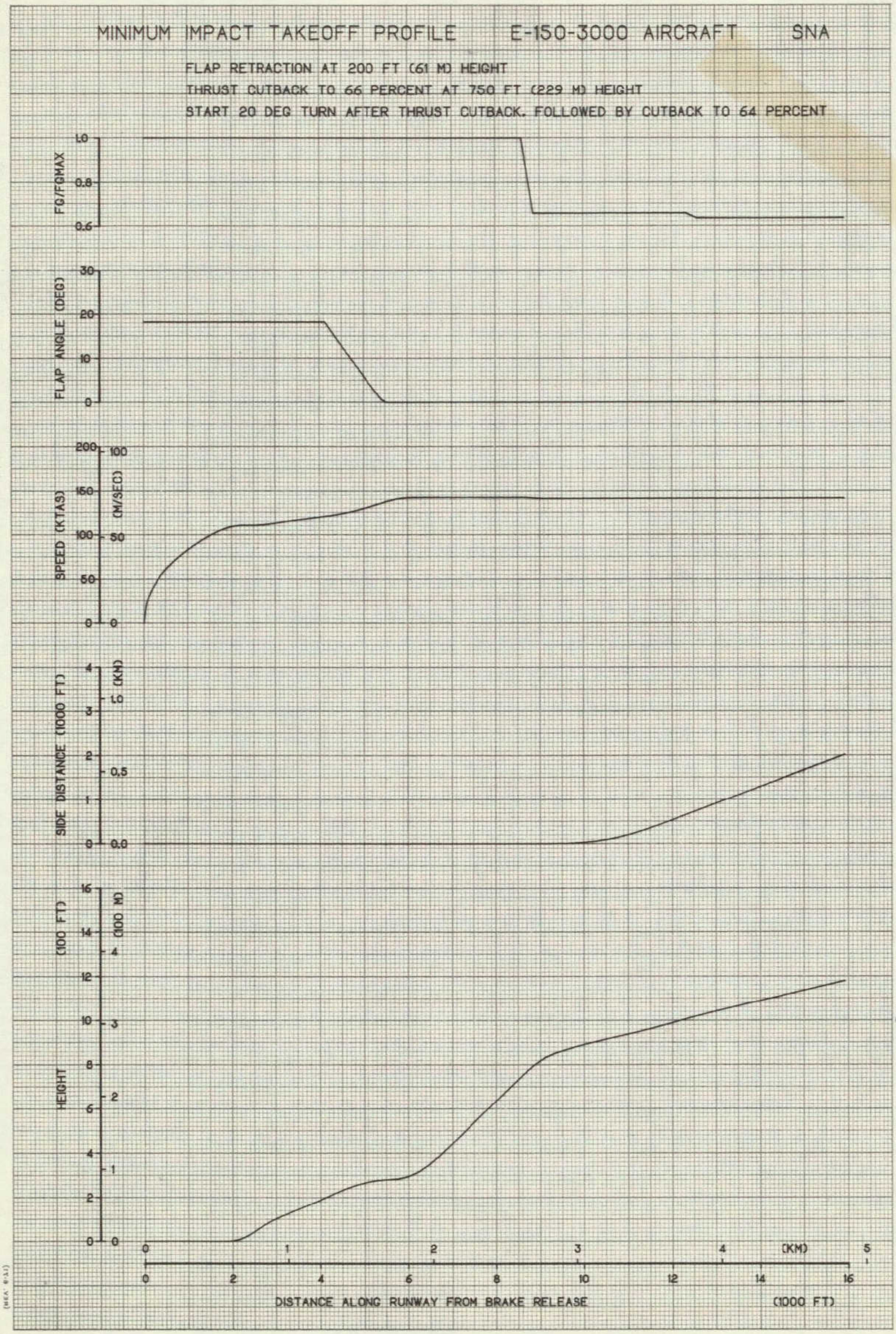

MINIMUM IMPACT TAKEOFF PROFILE E-150-3000 AIRCRAFT SNA
FLAP RETRACTION AT 200 FT (61 M) HEIGHT
THRUST CUTBACK TO 66 PERCENT AT 750 FT (229 M) HEIGHT
START 20 DEG TURN AFTER THRUST CUTBACK, FOLLOWED BY CUTBACK TO 64 PERCENT
FG/FGMAX
FLAP ANGLE (DEG)
SPEED (KTAS)
(M/SEC)
SIDE DISTANCE (1000 FT)
(KM)
HEIGHT (100 FT)
(100 M)
(KM)
DISTANCE ALONG RUNWAY FROM BRAKE RELEASE
(1000 FT)

FIGURE 5-52.

NOISE FOOTPRINTS — MINIMUM IMPACT PROCEDURE
ORANGE COUNTY AIRPORT, RWY 19 R — E·150·3000 AIRPLANE

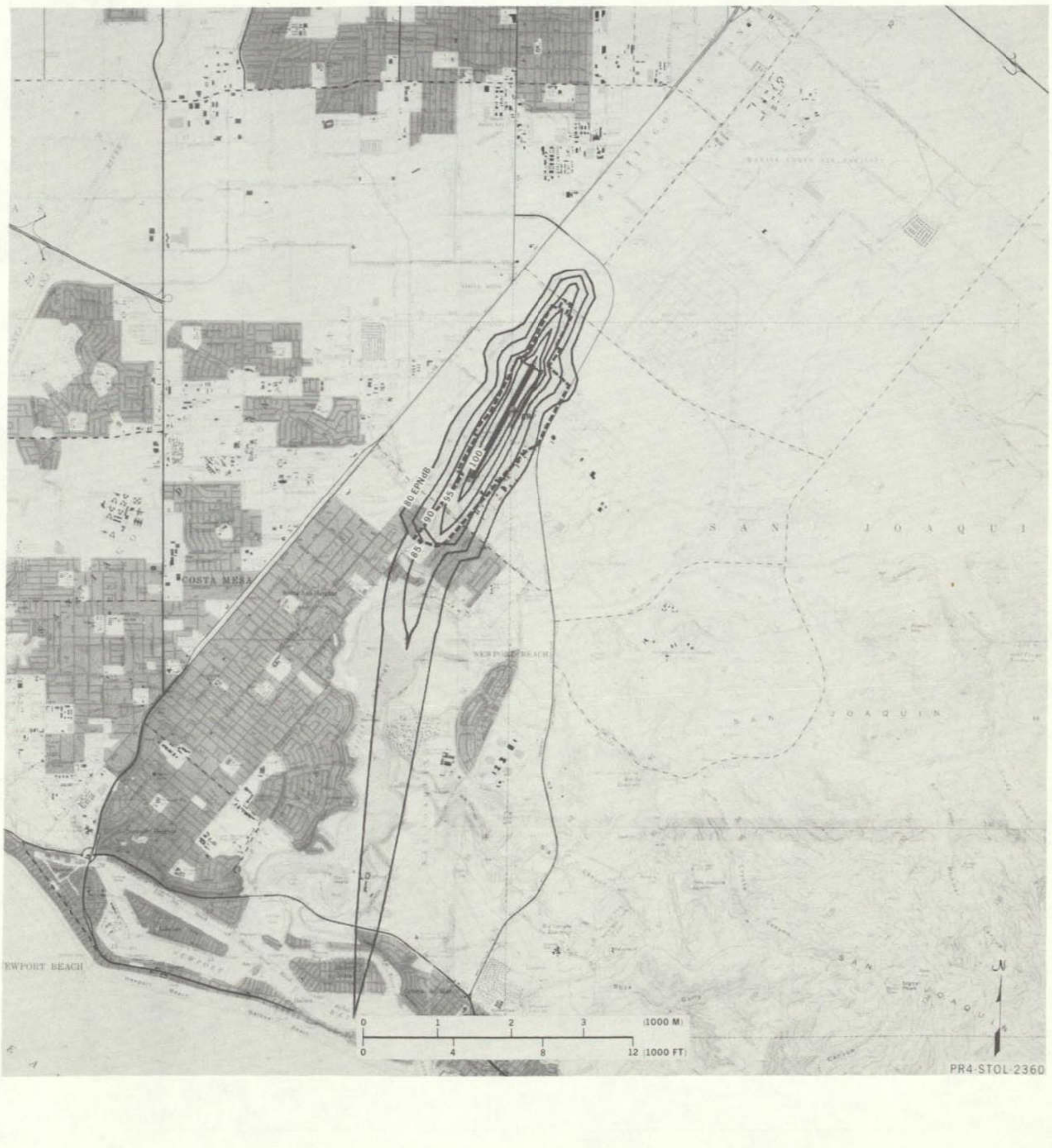


FIGURE 5-53.

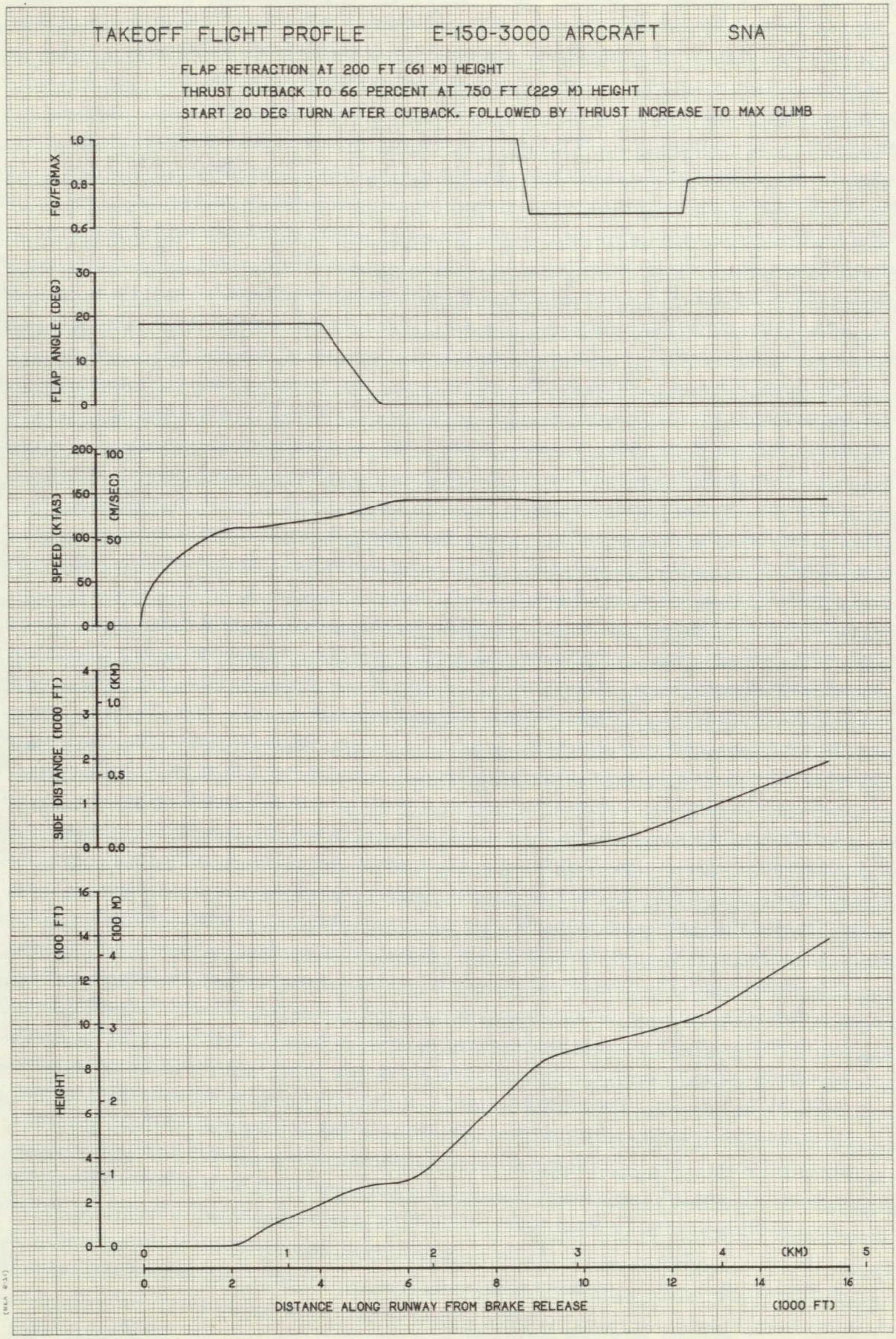

TAKEOFF FLIGHT PROFILE E-150-3000 AIRCRAFT SNA
FLAP RETRACTION AT 200 FT (61 M) HEIGHT
THRUST CUTBACK TO 66 PERCENT AT 750 FT (229 M) HEIGHT
START 20 DEG TURN AFTER CUTBACK. FOLLOWED BY THRUST INCREASE TO MAX CLIMB
FG/FGMAX
1.0
0.8
0.6
FLAP ANGLE (DEG)
30
20
10
0
SPEED (KTAS)
200
150
100
50
0
(M/SEC)
100
50
0
SIDE DISTANCE (1000 FT)
4
3
2
1
0
(KM)
1.0
0.5
0.0
HEIGHT
(100 FT)
16
14
12
10
8
6
4
2
0
(100 M)
4
3
2
1
0
0 1 2 3 4 (KM) 5
0 2 4 6 8 10 12 14 16
DISTANCE ALONG RUNWAY FROM BRAKE RELEASE (1000 FT)

FIGURE 5-54.

NOISE FOOTPRINTS — POWER VARIATION PROCEDURE
ORANGE COUNTY AIRPORT, RWY 19R — E·150·3000 AIRPLANE

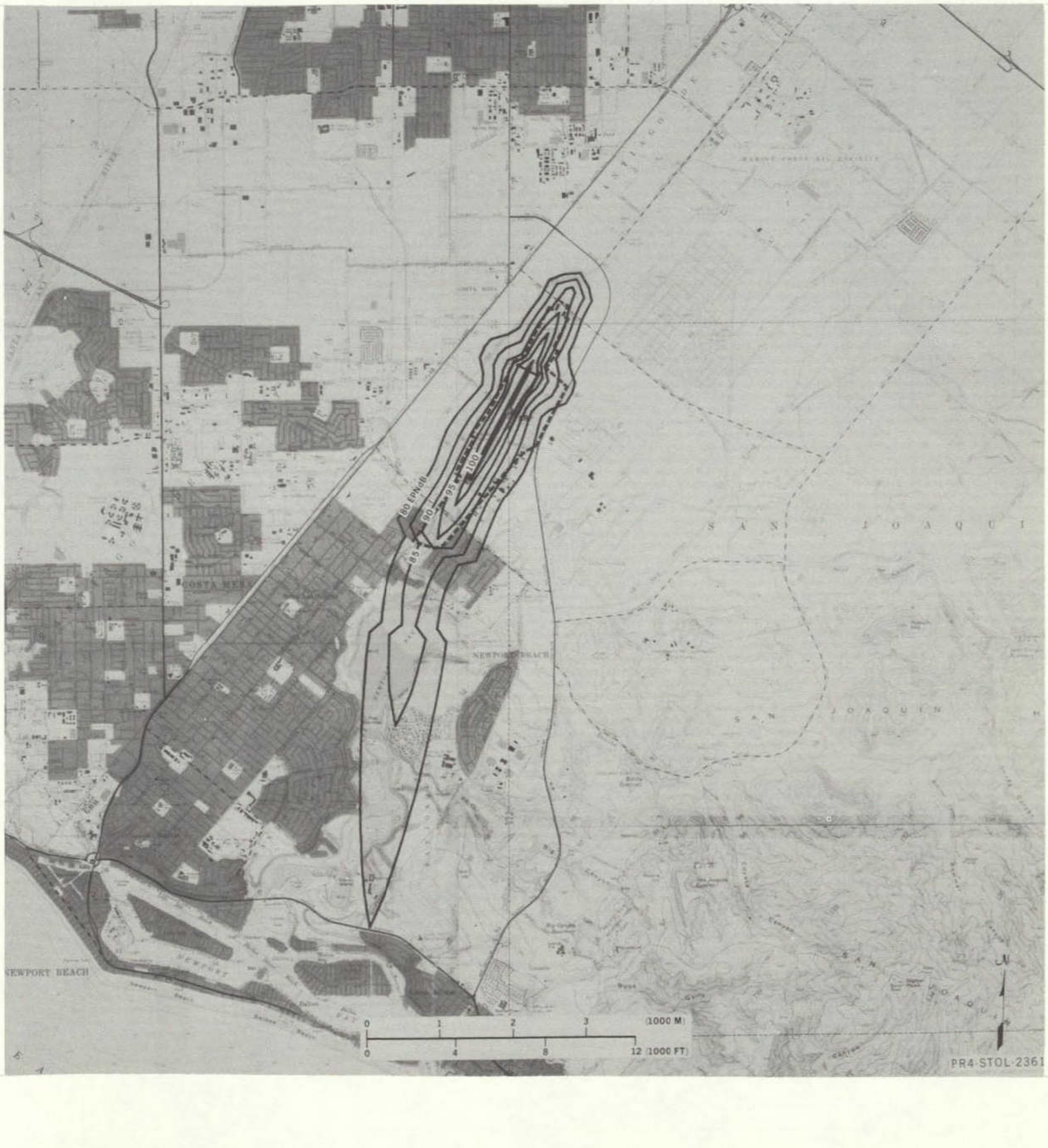


FIGURE 5-55.

A summary of the standard, low-impact, and minimum-impact procedures is presented in Table 5-7. The total population affected and number of highly annoyed persons are summarized for each procedure. The low-impact procedure resulted in a 31 percent reduction in persons annoyed by the 80 EPNdB footprint relative to the standard procedure. The minimum-impact procedure further reduced the community noise impact an additional 9 percent for a total reduction of 40 percent over the standard procedure.

5.6.4.4 Noise Impact - MIDWAY AIRPORT - The community noise evaluation of the standard, low-impact, and minimum-impact flight procedures of the E-150-3000 airplane at Chicago's Midway Airport is presented below. The evaluation was conducted for Runways 22L and 31L since both are high usage runways.

Standard Procedure. The single-event noise footprints using the baseline or standard procedure are shown in Figure 5-56. Except for a small portion of the approach lobe, the 100 EPNdB footprints are contained within the airport boundary. The approach and takeoff lobes of the 95 to 80 EPNdB footprints extend into the residential areas at the end of each runway as shown.

Low-Impact Procedure. The single-event noise footprints of the low-impact procedure at each runway are shown in Figure 5-57.

Minimum-Impact Procedure. A total of seventeen different takeoff flight procedures were evaluated for Midway Airport Runway 22L. The flight procedure which resulted in minimum impact is plotted in Figure 5-58. The procedure combines a power cutback to 66 percent gross takeoff thrust at an altitude of 500 feet (152 m) with a 45 degree (.785 radian) right turn initiated at

TABLE 5-7

NOISE IMPACT SUMMARY - E.150.3000 AIRPLANE

ORANGE COUNTY AIRPORT - RUNWAY 19R

EPNL Contour	STANDARD PROCEDURE				LOW IMPACT-PROCEDURE				MINIMUM-IMPACT PROCEDURE			
	Contour Area		Population		Contour Area		Population		Contour Area		Population	
	Sq.Mi.	Sq.Km.	Affected	Annoyed	Sq.Mi.	Sq.Km.	Affected	Annoyed	Sq.Mi.	Sq.Km.	Affected	Annoyed
100	0.18	0.45	5	3	0.18	0.46	5	3	0.18	0.46	5	3
95	0.44	1.14	131	44	0.38	0.98	143	48	0.38	0.98	143	48
90	0.92	2.38	769	201	0.73	1.90	582	158	0.70	1.81	383	109
85	1.71	4.43	1808	354	1.22	3.16	1169	249	1.22	3.16	1126	214
80	3.19	8.27	4882	468	2.61	6.77	3857	324	2.89	7.49	3067	282

NOISE FOOTPRINTS — STANDARD FLIGHT PROCEDURE
MIDWAY AIRPORT, RWYS 22L, 31L — E·150·3000 AIRPLANE

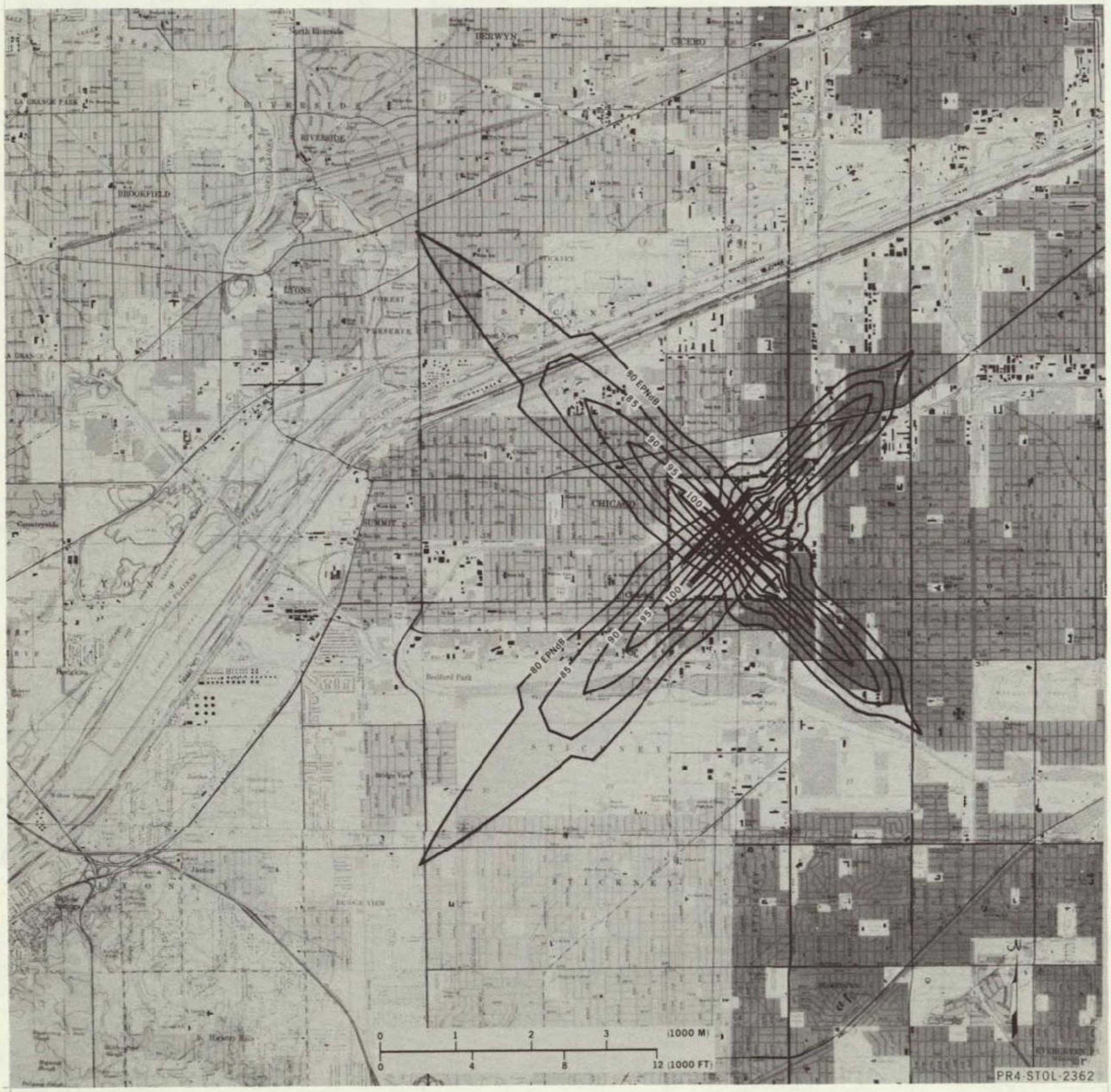


FIGURE 5-56.

NOISE FOOTPRINTS — LOW IMPACT PROCEDURE
MIDWAY AIRPORT, RWS 22L, 31L — E·150·3000 AIRPLANE

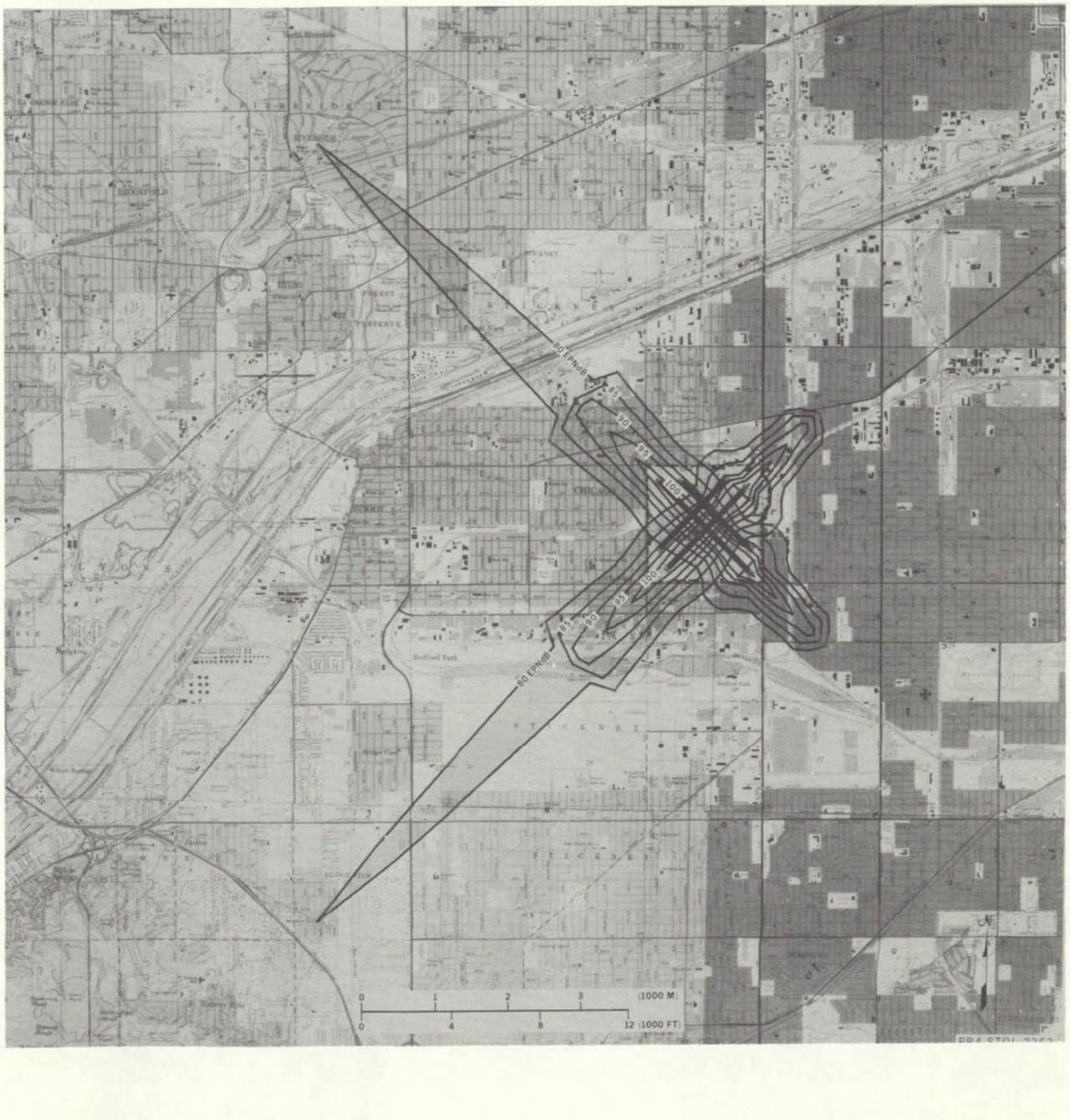
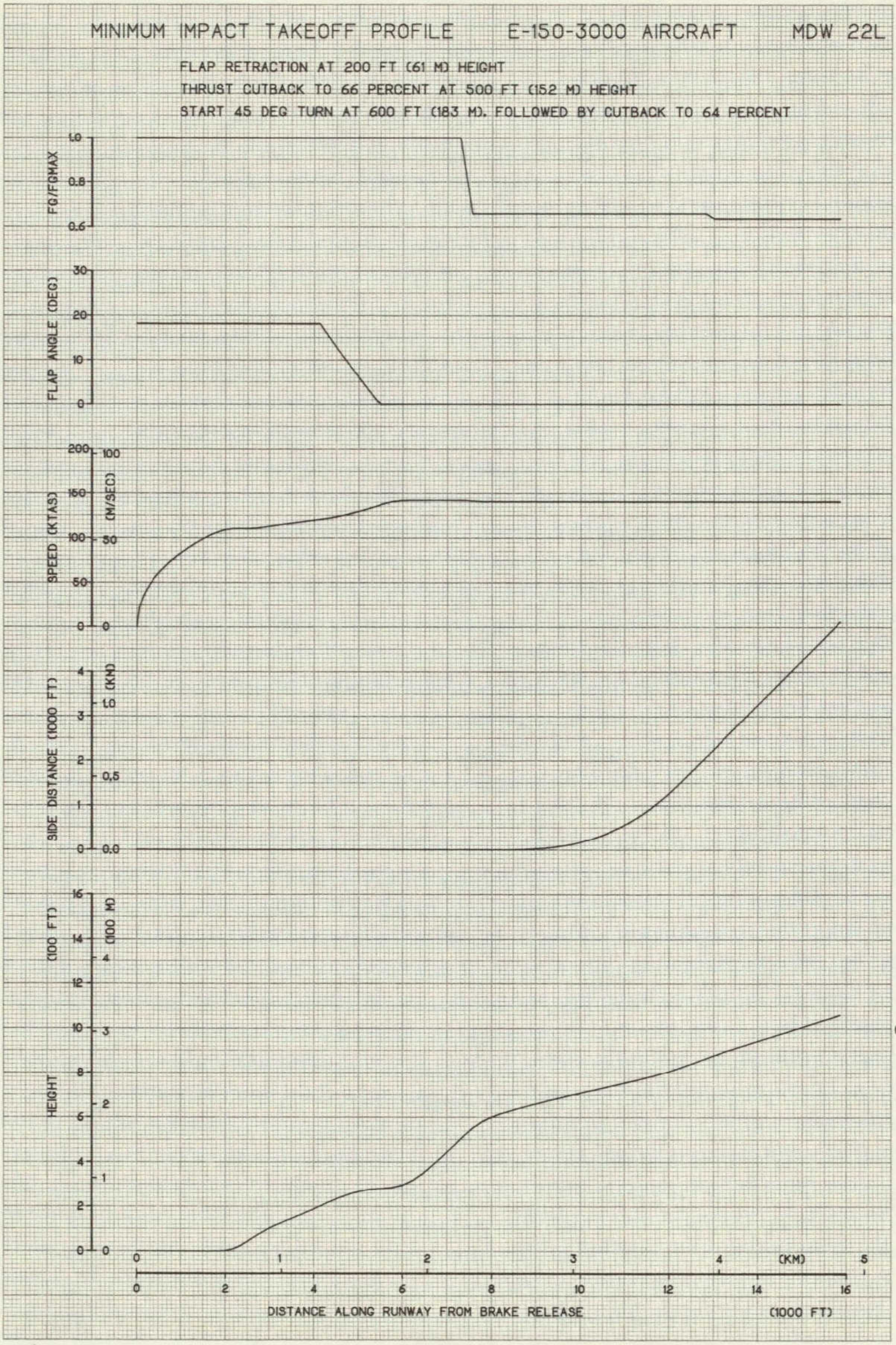


FIGURE 5-57.



MINIMUM IMPACT TAKEOFF PROFILE E-150-3000 AIRCRAFT MDW 22L
FLAP RETRACTION AT 200 FT (61 M) HEIGHT
THRUST CUTBACK TO 66 PERCENT AT 500 FT (152 M) HEIGHT
START 45 DEG TURN AT 600 FT (183 M), FOLLOWED BY CUTBACK TO 64 PERCENT
FG/FGMAX
FLAP ANGLE (DEG)
SPEED (KTAS)
(M/SEC)
SIDE DISTANCE (1000 FT)
(KM)
HEIGHT
(100 FT)
(100 M)
(KM)
DISTANCE ALONG RUNWAY FROM BRAKE RELEASE
(1000 FT)

FIGURE 5-58.

600 feet (183 m) and subsequent power cutback to 64 percent. This procedure directed the flight path over the unpopulated railroad classification yards in the Stickney district south and west of the airport as shown in Figure 5-59.

The minimum-impact procedure lengthens the 85 and 80 EPNdB takeoff lobes due to the reduced climb gradient, however, the lobes extend over relatively unpopulated industrial areas. The one school located within the minimum-impact footprint is exposed to a level of only 85 EPNdB on takeoff. A similar procedure proved the most effective of seventeen takeoff flight procedures evaluated using Midway's Runway 31L. Power cutback amount and altitude were identical but a 45 degree (.785 radian) left turn was initiated at a slightly higher altitude of 700 feet (213 m) to impact on the relatively unpopulated industrial area west of the Chicago sanitary and ship canal. The minimum-impact procedure for Runway 31L is plotted in Figure 5-60. The resultant noise footprints were shown in the previous Figure 5-59. A total of four schools and a monastery are contained within the noise impact area, however none are exposed to a noise level greater than 85 EPNdB.

A summary table of the standard, low-impact, and minimum-impact flight procedures for the E-150-3000 airplane at Midway Airport, Runway 22L is presented in Table 5-8. The low-impact procedure resulted in a 39 percent reduction in persons highly annoyed compared to the baseline case and the minimum-impact procedure resulted in a 45 percent reduction over the baseline.

As shown in Table 5-9 which summarizes the noise impact on Runway 31L, the low-impact procedure resulted in a 25 percent reduction in persons

NOISE FOOTPRINTS — MINIMUM IMPACT PROCEDURE
MIDWAY AIRPORT, RWYS 22L, 31L — E·150·3000 AIRPLANE

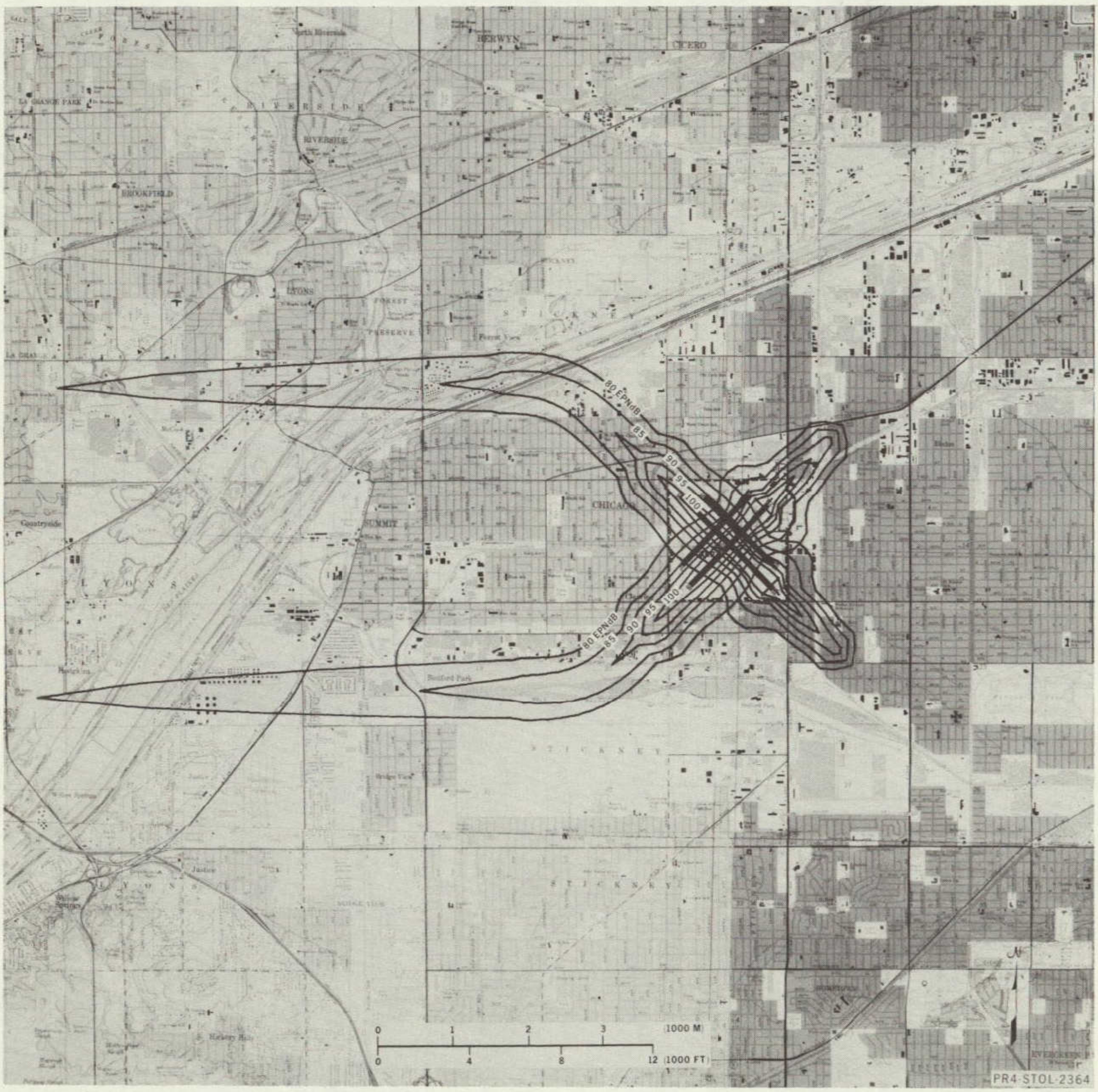


FIGURE 5-59.

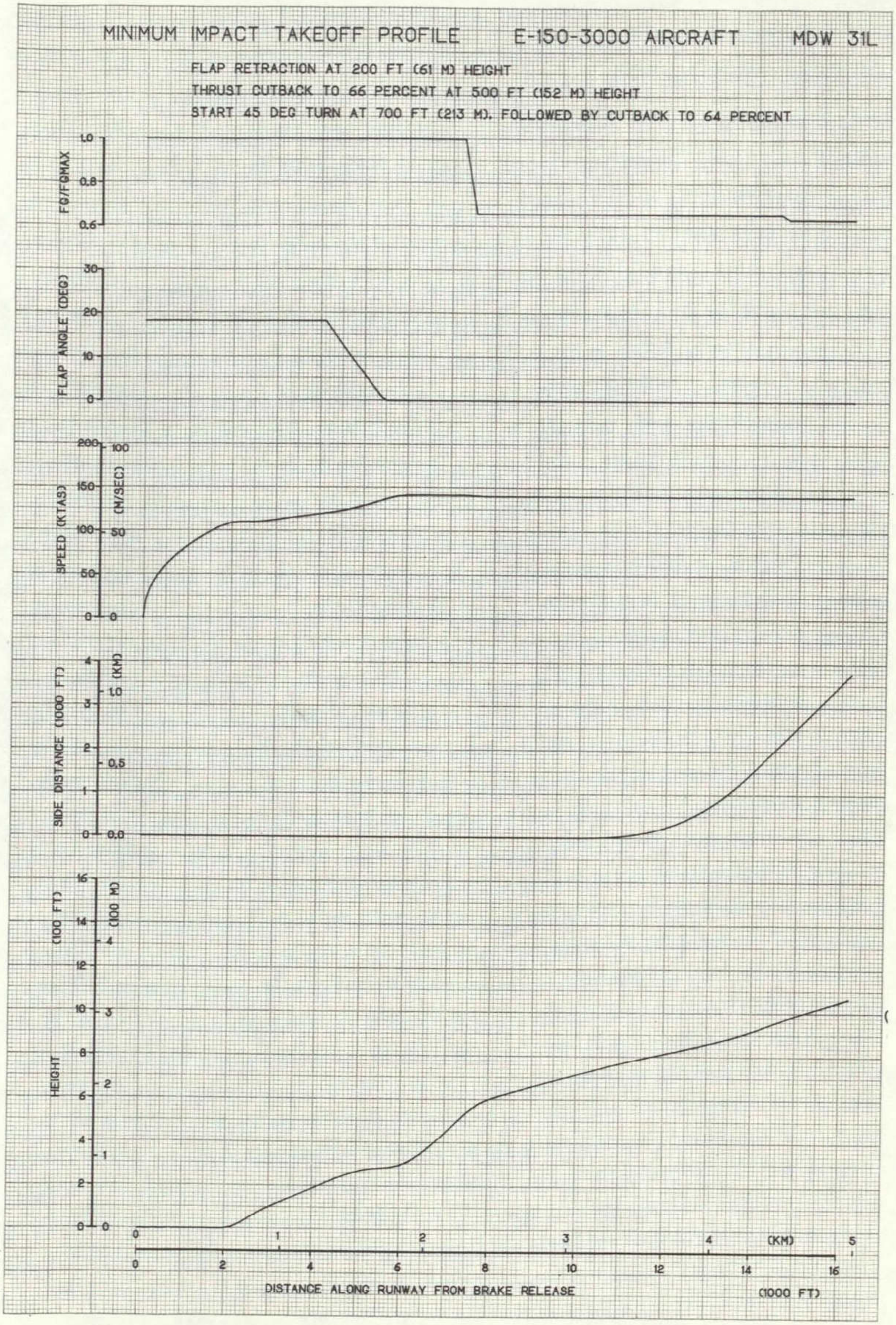

MINIMUM IMPACT TAKEOFF PROFILE E-150-3000 AIRCRAFT MDW 31L
FLAP RETRACTION AT 200 FT (61 M) HEIGHT
THRUST CUTBACK TO 66 PERCENT AT 500 FT (152 M) HEIGHT
START 45 DEG TURN AT 700 FT (213 M), FOLLOWED BY CUTBACK TO 64 PERCENT
FG/FGMAX
FLAP ANGLE (DEG)
SPEED (KTAS)
(M/SEC)
SIDE DISTANCE (1000 FT)
(KM)
HEIGHT
(100 FT)
(100 M)
(KM)
DISTANCE ALONG RUNWAY FROM BRAKE RELEASE
(1000 FT)

FIGURE 5-60.

TABLE 5-8

NOISE IMPACT SUMMARY - E.150.3000 AIRPLANE

MIDWAY AIRPORT - RUNWAY 22L

EPNL Contour	STANDARD PROCEDURE				LOW-IMPACT PROCEDURE				MINIMUM-IMPACT PROCEDURE			
	Contour Area		Population		Contour Area		Population		Contour Area		Population	
	Sq.Mi.	Sq.Km.	Affected	Annoyed	Sq.Mi.	Sq.Km.	Affected	Annoyed	Sq.Mi.	Sq.Km.	Affected	Annoyed
100	0.18	0.45	94	39	0.18	0.46	0	0	0.18	0.46	0	0
95	0.44	1.14	1343	455	0.38	0.98	952	329	0.37	0.97	814	280
90	0.92	2.38	4005	1119	0.73	1.90	2212	666	0.62	1.62	1800	543
85	1.71	4.43	7187	1595	1.22	3.16	4466	1000	1.35	3.49	3778	855
80	3.19	8.27	11960	1819	2.61	6.77	8018	1117	3.21	8.32	6895	997

TABLE 5-9

NOISE IMPACT SUMMARY - E.150.3000 AIRPLANE

MIDWAY AIRPORT - RUNWAY 31L

EPNL Contour	STANDARD PROCEDURE				LOW-IMPACT PROCEDURE				MINIMUM-IMPACT PROCEDURE			
	Contour Area		Population		Contour Area		Population		Contour Area		Population	
	Sq.Mi.	Sq.Km.	Affected	Annoyed	Sq.Mi.	Sq.Km.	Affected	Annoyed	Sq.Mi.	Sq.Km.	Affected	Annoyed
100	0.18	0.45	0	0	0.18	0.46	101	41	0.18	0.46	101	41
95	0.44	1.14	1553	529	0.38	0.98	997	340	0.37	0.97	795	275
90	0.92	2.38	4969	1368	0.73	1.90	3743	995	0.62	1.62	2427	662
85	1.71	4.43	8682	1909	1.22	3.16	6395	1388	1.34	3.48	5687	1142
80	3.19	8.27	15559	2168	2.61	6.77	12780	1619	3.19	8.27	9956	1322

highly annoyed compared to the baseline procedure. The minimum-impact procedure provided an additional 14 percent reduction, or a total reduction of 39 percent compared to the standard procedure.

5.6.5 Evaluation of EBF Aircraft with Oversized Engines - An E-150-3000 EBF airplane with 10 percent oversized engines was selected for evaluation as previously discussed in Sections 3.3 and 5.4.4. The evaluation was conducted using Midway Airport Runways 22L and 31L as this airport and runway combination has the largest population concentration of the four study airports. Results of the evaluation are directly comparable to the results of the basic E-150-3000 airplane since similar flight procedures were used.

Development of a low-impact procedure for this airplane was considered unnecessary since it is similar to the baseline E-150-3000 airplane.

Standard Procedure. The takeoff and landing profiles for the standard flight procedure for this aircraft were shown in Figures 5-17 and 5-21 respectively. The resultant single-event noise footprints for Midway Runways 22L and 31L are shown in Figure 5-61. The footprints are similar in shape to those of the basic E-150-3000 airplane previously presented in Figure 5-56.

Minimum-Impact Procedure. The minimum-impact takeoff profiles for the E-150-3000 airplane with 10 percent oversized engines at Midway Runways 22L and 31L are shown in Figures 5-62 and 5-63 respectively. These procedures were similar to those of the basic E-150-3000 airplane except for degree of power cutback and turn altitude. The minimum-impact landing procedure is shown in Figure 5-64. The resultant noise footprints are shown in Figure 5-65.

NOISE FOOTPRINTS — STANDARD FLIGHT PROCEDURE
MIDWAY AIRPORT, RWYS 22L, 31L — E·150·3000 AIRPLANE
WITH 10% OVERSIZED ENGINES

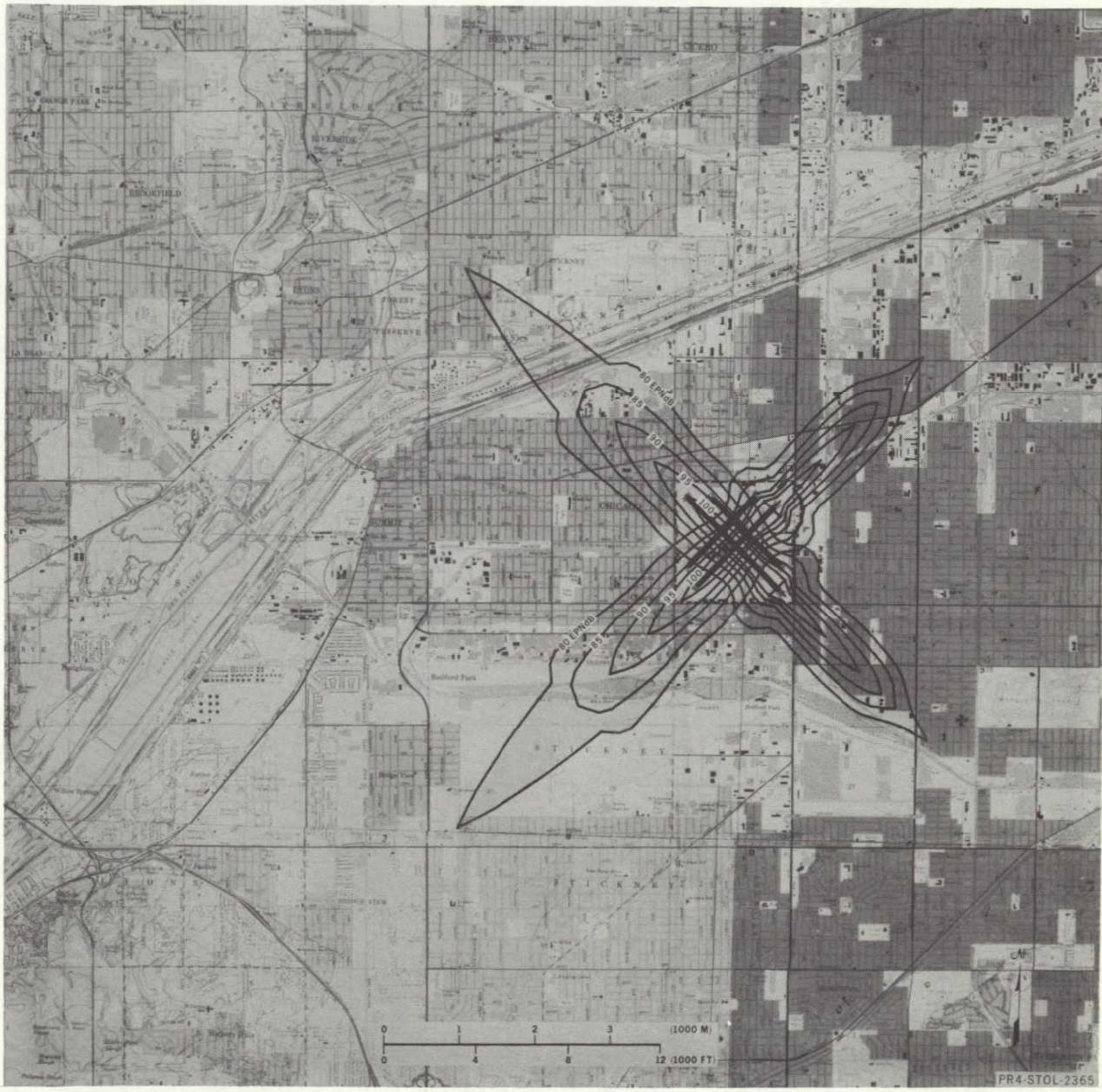


FIGURE 5-61.

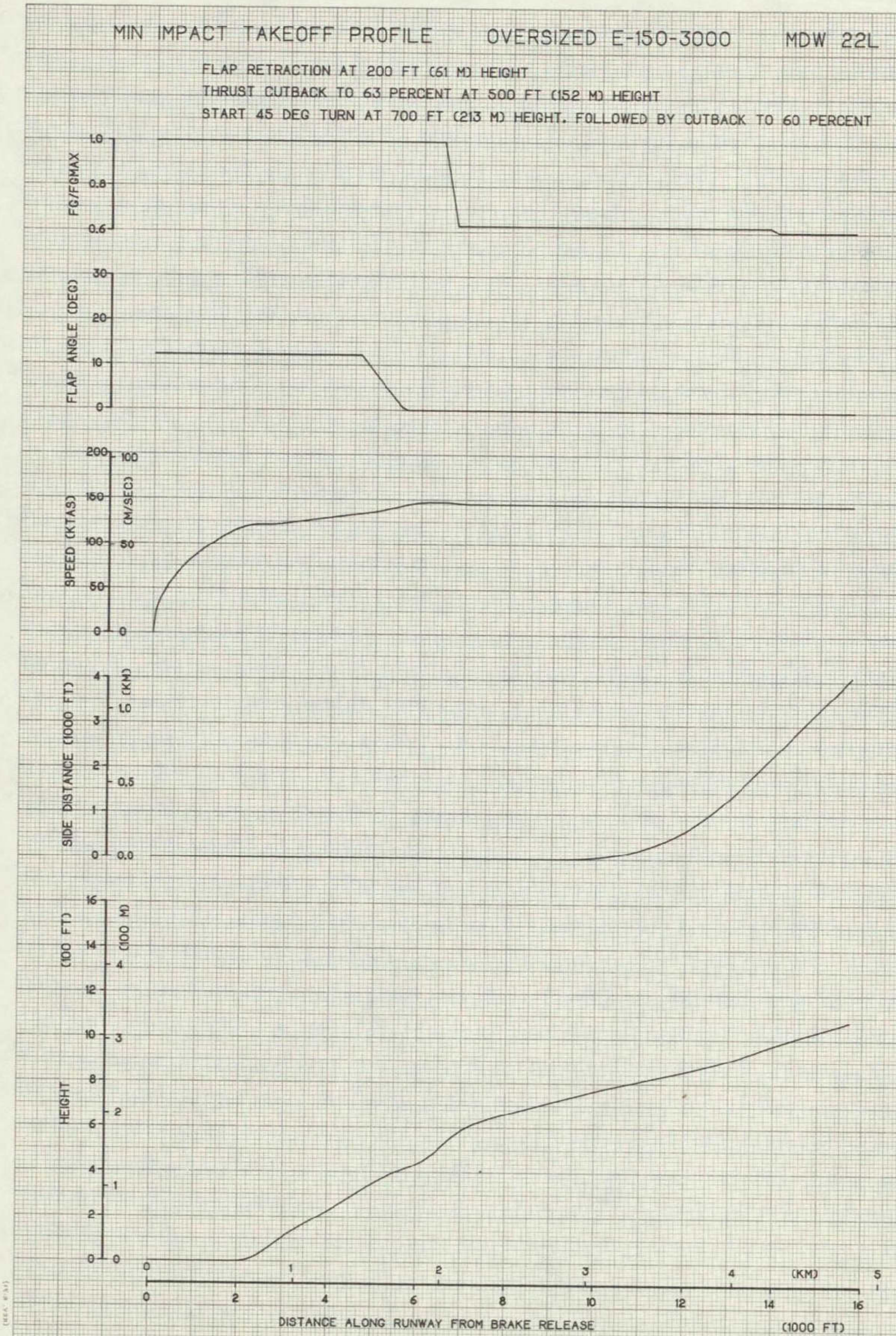

MIN IMPACT TAKEOFF PROFILE OVERSIZED E-150-3000 MDW 22L
FLAP RETRACTION AT 200 FT (61 M) HEIGHT
THRUST CUTBACK TO 63 PERCENT AT 500 FT (152 M) HEIGHT
START 45 DEG TURN AT 700 FT (213 M) HEIGHT. FOLLOWED BY CUTBACK TO 60 PERCENT
FG/FGMAX
FLAP ANGLE (DEG)
SPEED (KTAS)
(M/SEC)
SIDE DISTANCE (1000 FT)
(KM)
HEIGHT
(100 FT)
(100 M)
(KM)
DISTANCE ALONG RUNWAY FROM BRAKE RELEASE
(1000 FT)

FIGURE 5-62.

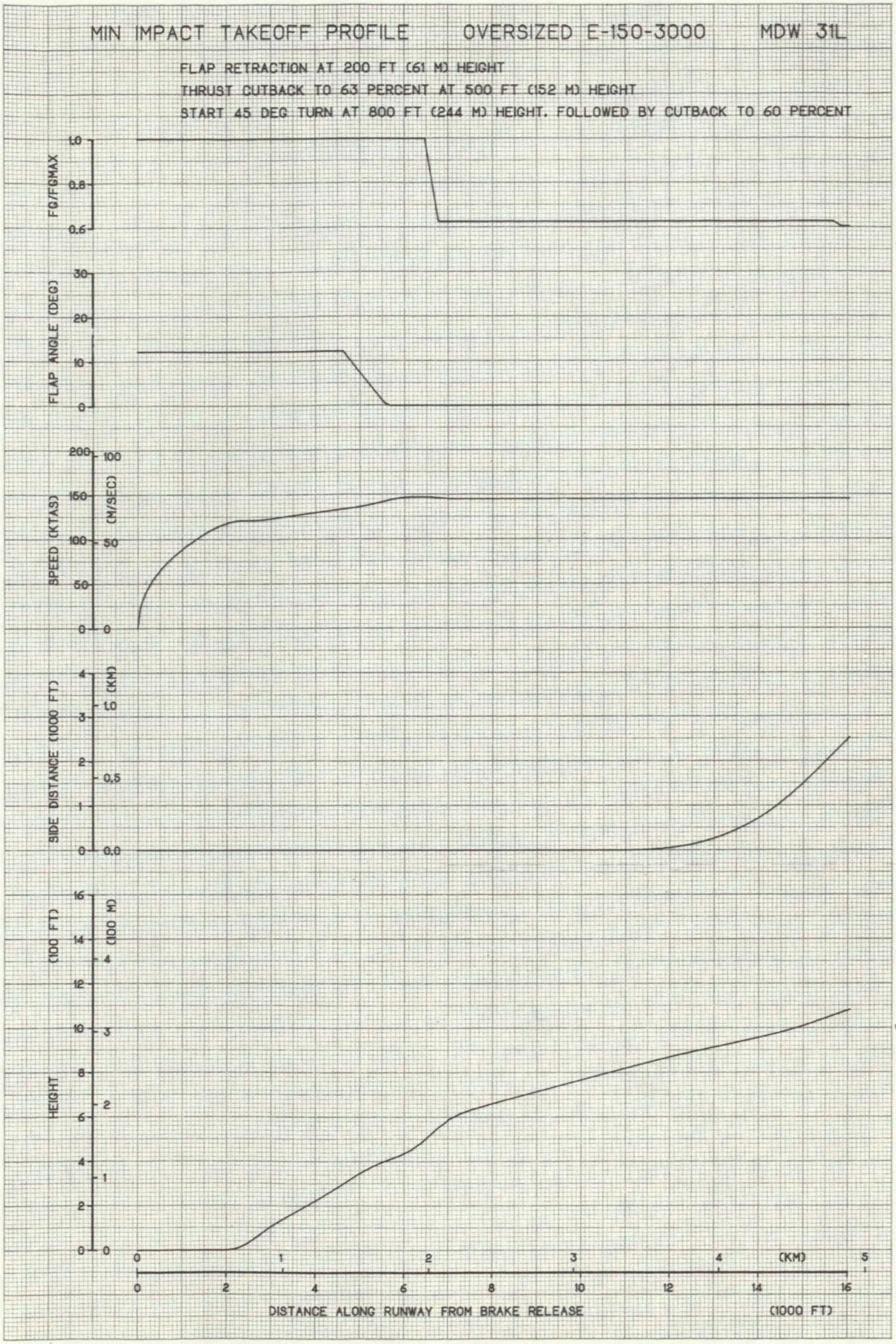

MIN IMPACT TAKEOFF PROFILE OVERSIZED E-150-3000 MDW 31L
FLAP RETRACTION AT 200 FT (61 M) HEIGHT
THRUST CUTBACK TO 63 PERCENT AT 500 FT (152 M) HEIGHT
START 45 DEG TURN AT 800 FT (244 M) HEIGHT. FOLLOWED BY CUTBACK TO 60 PERCENT
FG/FGMAX
FLAP ANGLE (DEG)
SPEED (KTAS)
(M/SEC)
SIDE DISTANCE (1000 FT)
(KM)
HEIGHT (100 FT)
(100 M)
(KM)
DISTANCE ALONG RUNWAY FROM BRAKE RELEASE
(1000 FT)

FIGURE 5-63

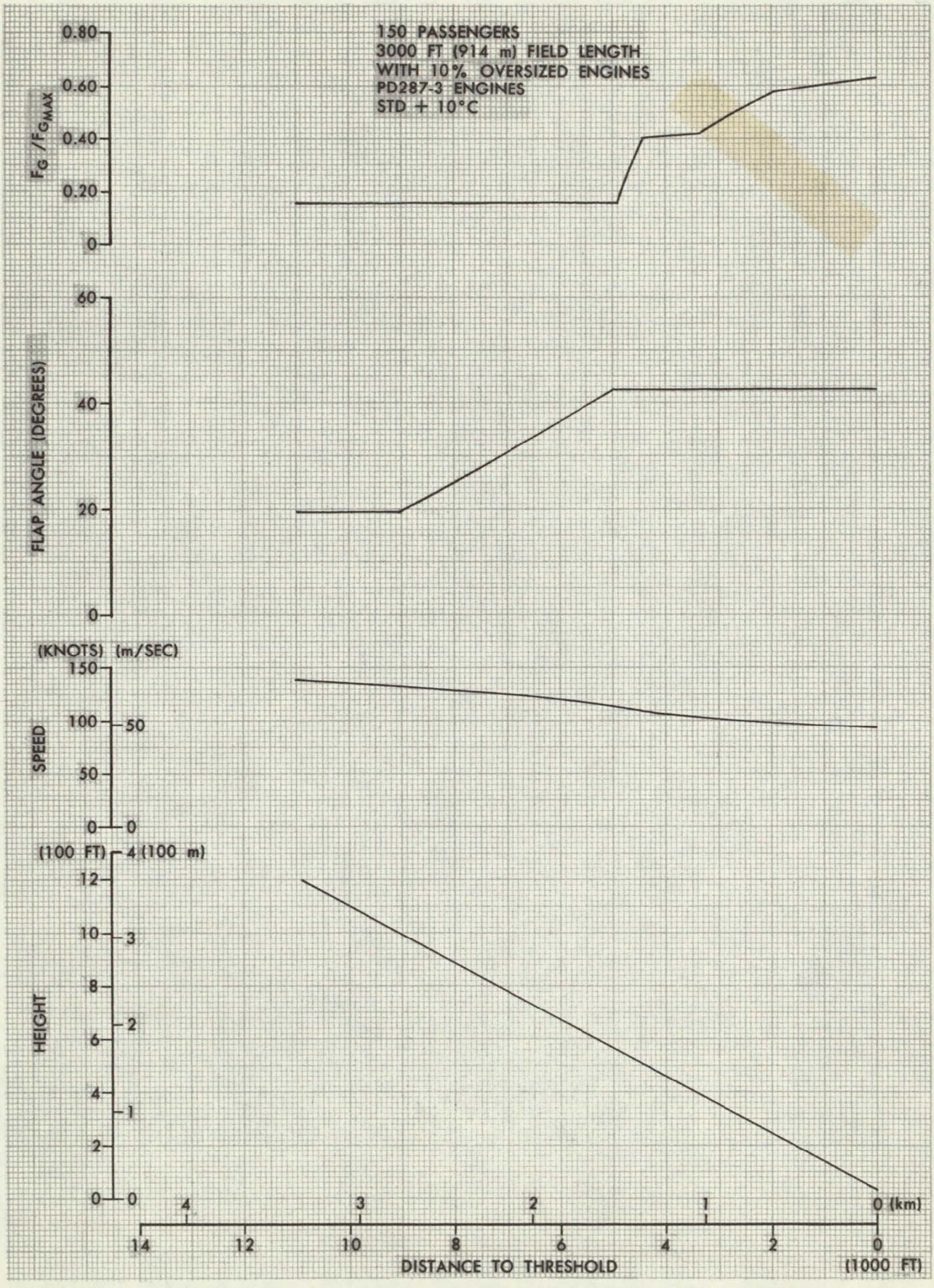


FIGURE 5-64. MINIMUM IMPACT LANDING APPROACH PROFILE—EXTERNALLY BLOWN FLAP AIRCRAFT—10 PERCENT OVERSIZED ENGINES

NOISE FOOTPRINTS — MINIMUM IMPACT PROCEDURE
MIDWAY AIRPORT, RWYS 22L, 31L — E·150·3000 AIRPLANE
WITH 10% OVERSIZED ENGINES

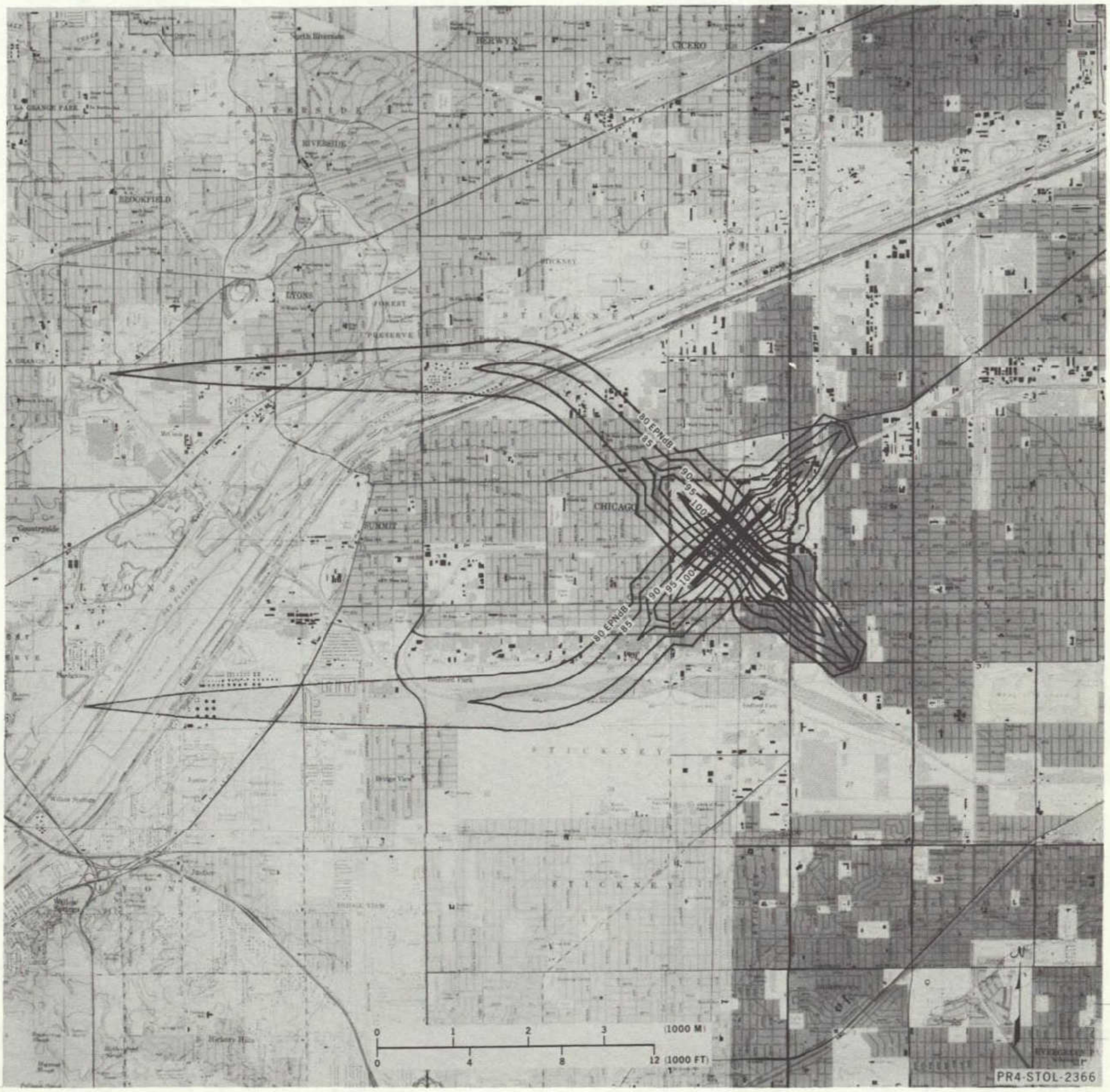


FIGURE 5-65.

Results of the noise impact evaluation of the E-150-3000 airplane with 10 percent oversized engines using Midway Runway 22L are summarized in Table 5-10. The minimum-impact procedure of this aircraft resulted in a 49 percent reduction over the comparable standard procedure. The oversized engine airplane on this runway also resulted in a 9 percent reduction in number of persons highly annoyed compared to the similar minimum-impact procedure for the basic E-150-3000 airplane.

A summary of the oversized engine airplane using Runway 31L is presented in Table 5-11. The minimum-impact procedure of the oversized engine airplane resulted in a 39 percent reduction in number of persons highly annoyed compared to the baseline procedure. The oversized engine airplane also resulted in a 7 percent reduction in persons highly annoyed compared to that of the basic E-150-3000 airplane for this airport and runway combination.

5.6.6 Community Noise Impact - MF Airplane - Aircraft characteristics and noise reduction flight operational techniques applicable to the two engine MF-150-4000 airplane were discussed in Sections 5.3 and 5.5. The results of applying those techniques to the four study airports are described in this section. The evaluation procedures were similar to those used in evaluating the community noise impact of the EBF airplane and discussed in Section 5.6.4. A standard and low-impact procedure which assumed a uniform population distribution was developed and evaluated at each airport and runway combination. The low-impact procedure was then modified to minimize population impact by tailoring the takeoff operational procedures to the specific airport configuration and population characteristics. The resultant procedure is termed the minimum-impact procedure.

TABLE 5-10

NOISE IMPACT SUMMARY - E.150.3000 AIRPLANE

10% OVERSIZED ENGINES

MIDWAY AIRPORT - RUNWAY 22L

EPN1 Contour	STANDARD PROCEDURE				LOW-IMPACT PROCEDURE*				MINIMUM-IMPACT PROCEDURE			
	Contour Area		Population		Contour Area		Population		Contour Area		Population	
	Sq.Mi.	Sq.Km.	Affected	Annoyed	Sq.Mi.	Sq.Km.	Affected	Annoyed	Sq.Mi.	Sq.Km.	Affected	Annoyed
100	0.17	0.44	94	40					0.16	0.41	45	18
95	0.41	1.05	943	321					0.35	0.91	457	154
90	0.85	2.21	3760	1032					0.59	1.52	1465	399
85	1.60	4.13	7423	1573					1.26	3.26	3816	760
80	2.95	7.63	12282	1776					2.99	7.75	6940	903

*NOTE: Low Impact flight procedure developed for basic E.150.3000 airplane also is applicable to oversized engine airplane. Low impact contour unnecessary for oversized engine case.

TABLE 5-11

NOISE IMPACT SUMMARY - E.150.3000 AIRPLANE

10% OVERSIZED ENGINES

MIDWAY AIRPORT - RUNWAY 31L

EPNL Contour	STANDARD PROCEDURE				LOW-IMPACT PROCEDURE*				MINIMUM-IMPACT PROCEDURE			
	Contour Area		Population		Contour Area		Population		Contour Area		Population	
	Sq.Mi.	Sq.Km.	Affected	Annoyed	Sq.Mi.	Sq.Km.	Affected	Annoyed	Sq.Mi.	Sq.Km.	Affected	Annoyed
100	0.17	0.44	0	0					0.16	0.41	0	0
95	0.41	1.05	1210	418					0.35	0.91	582	198
90	0.85	2.21	4338	1187					0.59	1.52	2187	568
85	1.60	4.13	9002	1866					1.26	3.27	5688	1042
80	2.95	7.63	14258	2032					2.97	7.68	10245	1236

*NOTE: Low Impact flight procedure developed for basic E.150.3000 airplane also is applicable to oversized engine airplane. Low impact contour unnecessary for oversized engine case.

The standard takeoff and landing flight profiles of the M-150-4000 airplane were previously shown in Figures 5-19 and 5-23 respectively. These profiles and the resultant noise footprints are identical for each airport.

The low-impact flight profiles of the takeoff and landing procedure for this aircraft were previously shown in Figures 5-36 and 5-37 respectively. These profiles and the resultant low-impact noise footprints also are identical for each airport and runway combination. As with the EBF airplane, the landing portions of the low-impact and minimum-impact procedures are identical. Takeoff profiles of the M-150-4000 minimum-impact procedures, however, differ for each airport and runway combination. Single-event noise contours for EPNLs of 100, 95, 90, 85, and 80 EPNdB were produced for each flight procedure.

The shape of the noise footprints of the M-150-4000 differ from those of the E-150-3000 airplane due to differences in design sideline noise levels and aircraft performance characteristics of the two aircraft types. The approach and takeoff lobes of the M-150-4000 footprints are slightly wider than the E-150-3000 due to the higher design sideline noise level. The takeoff lobes are shorter because of the greater climb gradient of the MF airplane.

5.6.6.1 Noise Impact - HANSCOM FIELD - The community noise impact evaluation of the standard, low-impact, and minimum-impact flight procedures of the M-150-4000 airplane is summarized below:

Standard Procedure. The single-event landing and takeoff noise footprints using the standard or baseline procedure are shown in Figure 5-66. As with the EBF airplane the 100 EPNdB footprint is essentially contained within the airport boundary.

NOISE FOOTPRINTS — STANDARD FLIGHT PROCEDURE
HANSCOM FIELD, RWY 5 — M.150.4000 AIRPLANE

FIGURE 5-66.

Low-Impact Procedure. The single-event landing and takeoff noise footprints of the low-impact procedure are shown in Figure 5-67.

Minimum-Impact Procedure. A total of twelve takeoff procedures were evaluated and it was found the straight flight path low-impact procedure also resulted in minimum impact. The technique used in this procedure involved raising the landing flaps at 250 feet (76 m) altitude with a power cutback to 66 percent of gross takeoff thrust initiated at an altitude of 750 feet (229 m). The resultant noise footprints were shown in Figure 5-67. As in the case of the EBF airplane, no schools are contained within the footprint areas.

Results of the community noise evaluation of M-150-4000 airplane airplane at Hanscom Field, Runway 5 are summarized in Table 5-12. The minimum-impact procedure resulted in a reduction of 33 percent in the number of persons highly annoyed compared to the standard or baseline procedure.

5.6.6.2 Noise Impact - WASHINGTON NATIONAL - The community noise evaluation of the standard, low-impact, and minimum-impact procedures of the M-150-4000 airplane at Washington National is discussed below.

Standard Procedure. The single-event landing and takeoff noise footprints using the standard procedure are shown in Figure 5-68. The 80 EPNdB footprint of the straight flight path projects slightly beyond Consitution Avenue near 19th Mtreet.

Low Impact Procedure. The single-event noise footprints of the low-impact procedure are shown in Figure 5-69. As noted,the power cutback of the straight flight path low-impact procedure narrowed and lengthened the 80 EPNdB spike of the takeoff lobe causing it to project slightly farther into downtown D.C.

NOISE FOOTPRINTS - LOW-IMPACT PROCEDURE
HANSCOM FIELD, RWY 5 — M·150·4000·AIRPLANE
(ALSO MINIMUM-IMPACT)

FIGURE 5-67.

TABLE 5-12

NOISE IMPACT SUMMARY - M.150.4000 AIRPLANE

HANSCOM FIELD - RUNWAY 5

EPNL Contour	STANDARD PROCEDURES				LOW-IMPACT PROCEDURE				MINIMUM-IMPACT PROCEDURE*			
	Contour Area		Population		Contour Area		Population		Contour Area		Population	
	Sq.Mi.	Sq.Km.	Affected	Annoyed	Sq.Mi.	Sq.Km.	Affected	Annoyed	Sq.Mi.	Sq.Km.	Affected	Annoyed
100	0.26	0.67	80	40	0.28	0.73	90	45	0.28	0.73	90	45
95	0.52	1.35	199	81	0.50	1.30	185	77	0.50	1.30	185	77
90	1.04	2.71	636	187	0.82	2.13	303	107	0.82	2.13	303	107
85	1.83	4.73	1372	298	1.45	3.75	857	186	1.45	3.75	857	186
80	3.29	8.52	2836	361	2.77	7.17	2136	243	2.77	7.17	2136	243

*NOTE: Low impact procedure also is the minimum impact procedure for this airport and runway combination.

NOISE FOOTPRINTS — STANDARD FLIGHT PROCEDURE
WASHINGTON NATIONAL, RWY 36 — M·150·4000 AIRPLANE

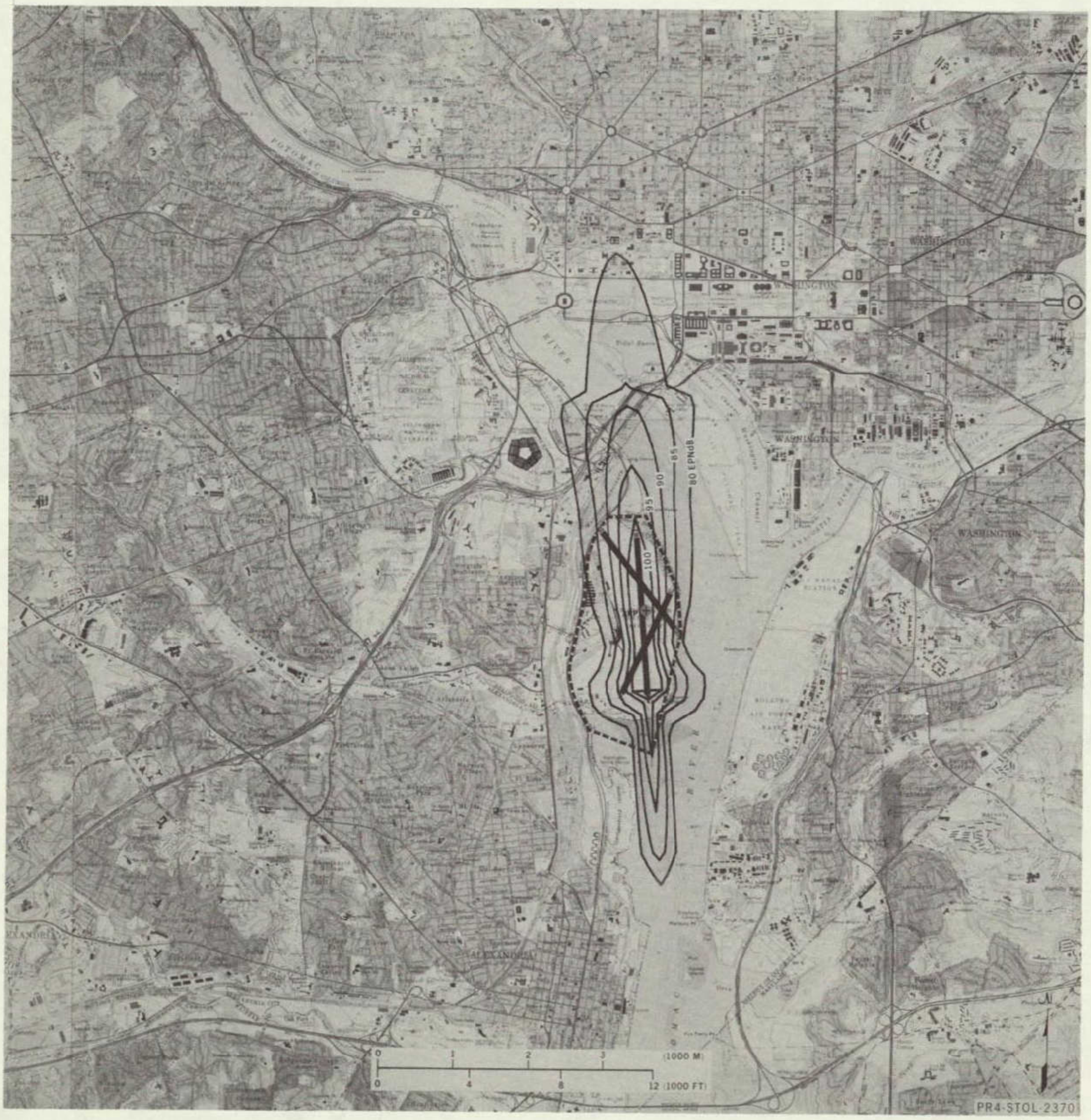


FIGURE 5-68.

NOISE FOOTPRINTS — LOW-IMPACT PROCEDURE
WASHINGTON NATIONAL, RWY 36 — M·150·4000 AIRPLANE

FIGURE 5-69.

Minimum-Impact Procedure. A total of seven takeoff techniques were evaluated before arriving at the minimum-impact procedure described in Figure 5-70. This technique involved raising the landing flaps at an altitude of 250 feet (76 m) and initiating a 30 degree (.524 radian) left turn at 500 feet (152 m) altitude. Power was subsequently reduced to 66 percent gross takeoff thrust upon reaching an altitude of 1450 feet (442 m). Although this procedure widened the takeoff lobes of the 85 and 80 EPNdB footprints as shown in Figure 5-71, the footprints do not impact on populated areas. The minimum-impact procedure resulted in zero population impact.

Standard Flight Procedure - Runway 18. The standard flight procedure of the M-150-4000 airplane also was evaluated using a southbound straight approach and departure on Runway 18. As shown in Figure 5-72, the footprints are wider than those of the EBF airplane, however, the footprint land impact is over unpopulated riverbank areas of the Potomac. The resultant population impact of the standard procedure was zero and eliminated the need of investigating additional techniques for this runway.

The results of the community noise evaluation of the M-150-4000 airplane at Washington National Airport are summarized in Table 5-13. The minimum-impact procedure on Runway 36 and the standard procedure on Runway 18 both resulted in zero population exposure.

5.6.6.3 Noise Impact - ORANGE COUNTY AIRPORT - The community noise impact evaluation of the standard, low-impact, and minimum-impact procedures for the M-150-4000 airplane at Orange County Airport Runway 19R is discussed below.

Standard Procedure. The single-event landing and takeoff noise footprints

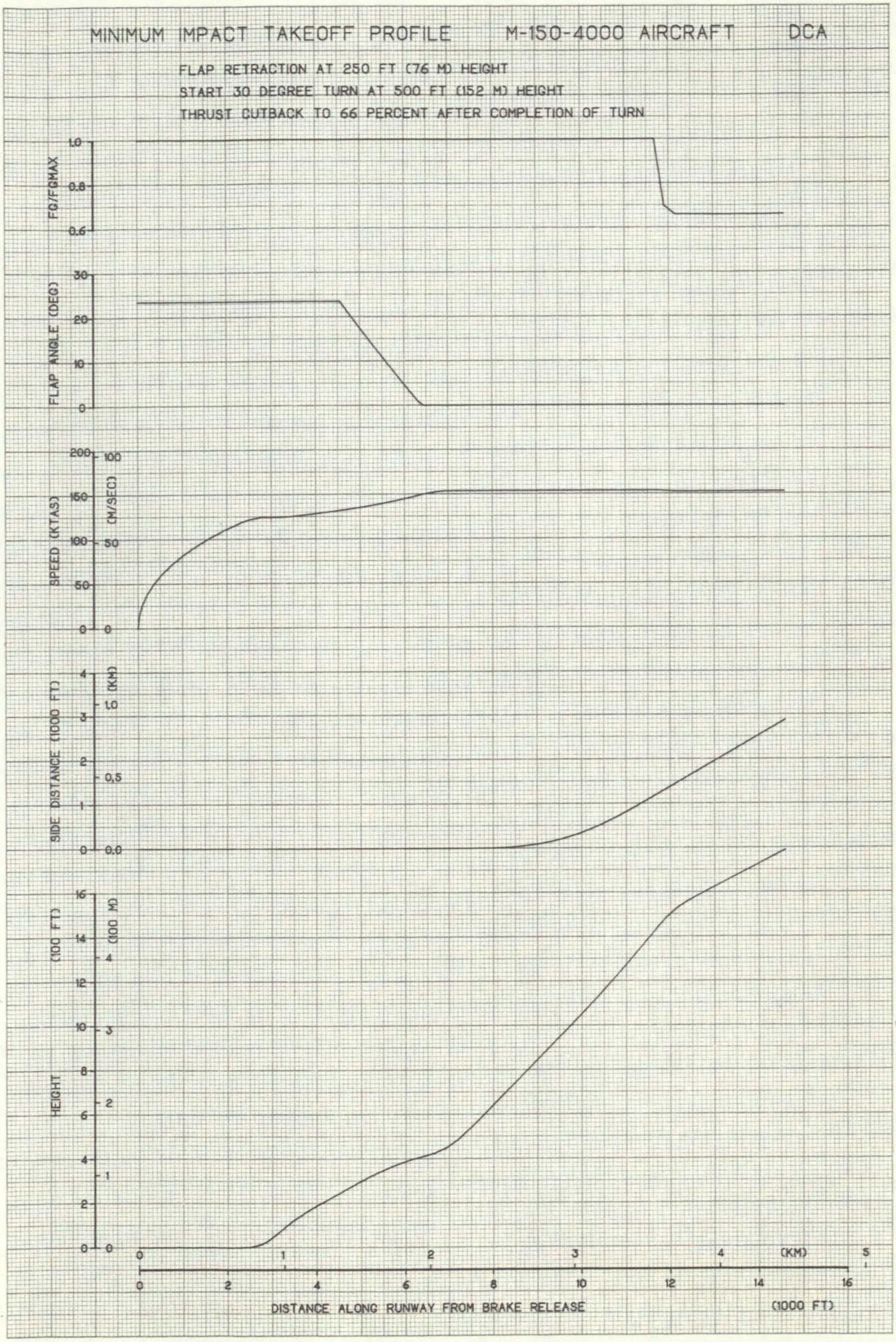

MINIMUM IMPACT TAKEOFF PROFILE M-150-4000 AIRCRAFT DCA
FLAP RETRACTION AT 250 FT (76 M) HEIGHT
START 30 DEGREE TURN AT 500 FT (152 M) HEIGHT
THRUST CUTBACK TO 66 PERCENT AFTER COMPLETION OF TURN
FG/FGMAX
FLAP ANGLE (DEG)
SPEED (KTAS)
(M/SEC)
SIDE DISTANCE (1000 FT)
(KM)
HEIGHT (100 FT)
(100 M)
(KM)
DISTANCE ALONG RUNWAY FROM BRAKE RELEASE
(1000 FT)

FIGURE 5-70.

NOISE FOOTPRINTS — MINIMUM IMPACT PROCEDURE
WASHINGTON NATIONAL, RWY 36 — M·150·4000 AIRPLANE

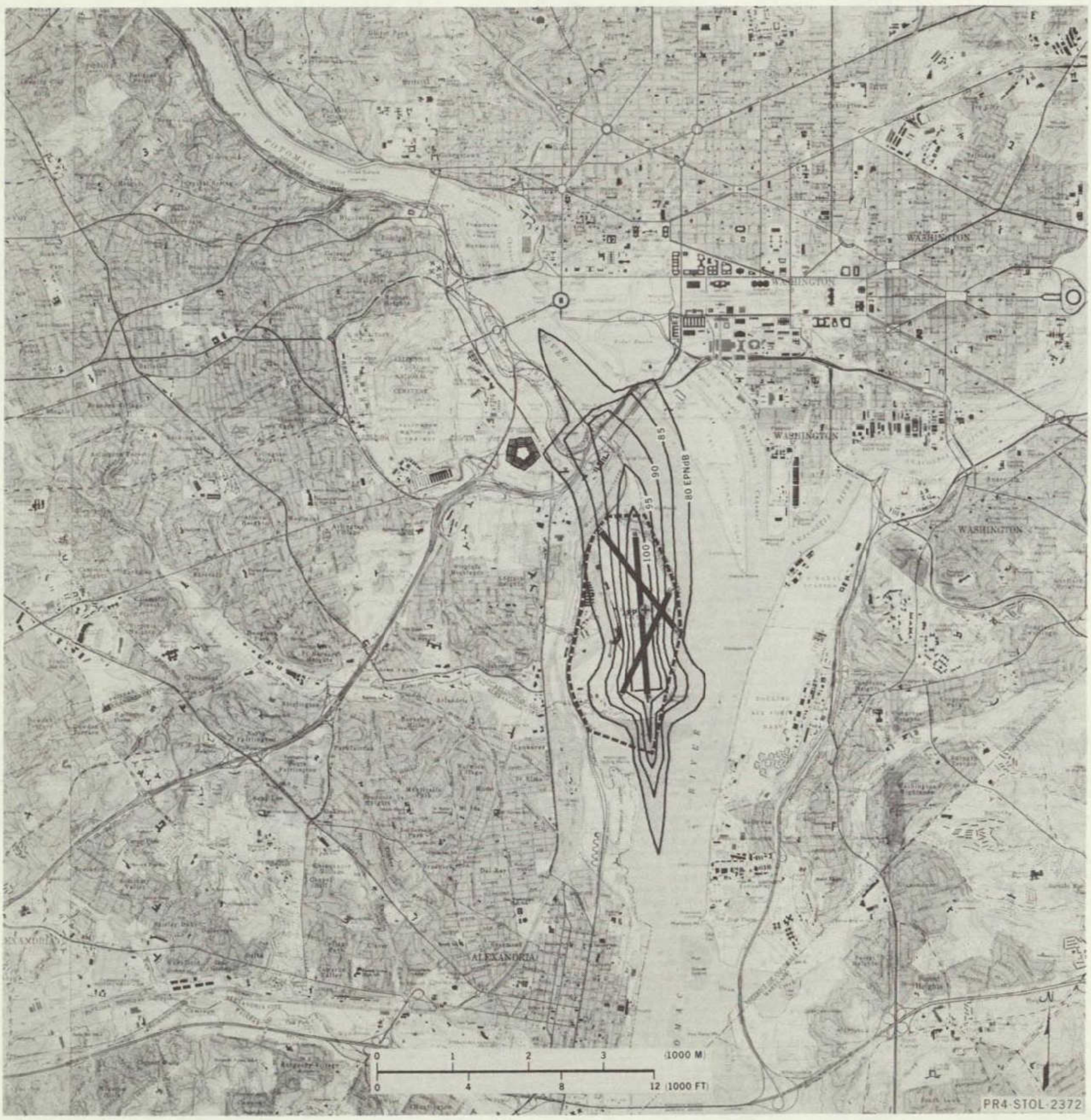


FIGURE 5-71.

NOISE FOOTPRINTS — STANDARD FLIGHT PROCEDURE
WASHINGTON NATIONAL, RWY 18 — M·150·4000 AIRPLANE

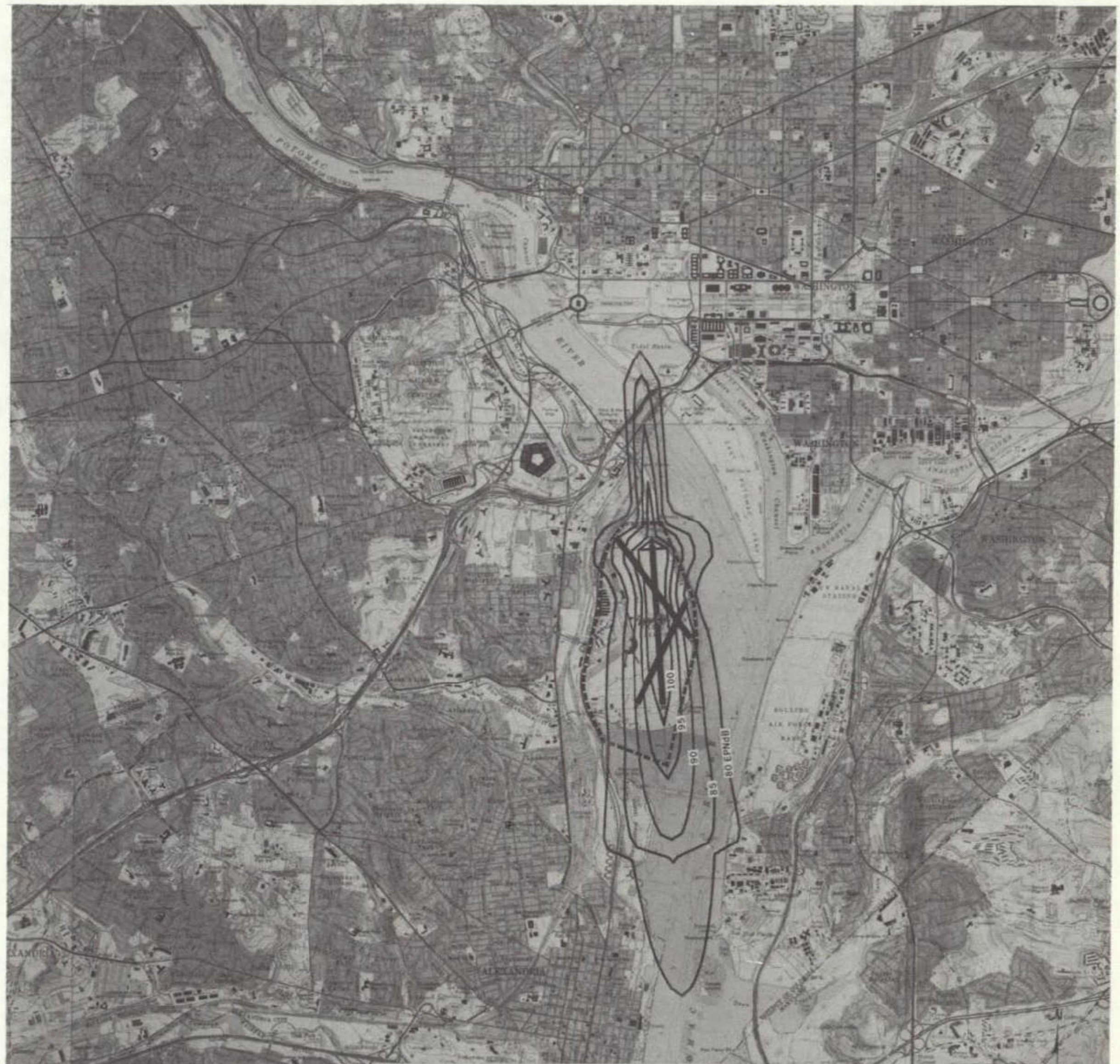


FIGURE 5-72.

TABLE 5-13

NOISE IMPACT SUMMARY - M.150.4000 AIRPLANE

WASHINGTON NATIONAL - RUNWAY 36*

EPNL Contour	STANDARD PROCEDURE				LOW-IMPACT PROCEDURE				MINIMUM-IMPACT PROCEDURE			
	Contour Area		Population		Contour Area		Population		Contour Area		Population	
	Sq.Mi.	Sq.Km.	Affected	Annoyed	Sq.Mi.	Sq.Km.	Affected	Annoyed	Sq.Mi.	Sq.Km.	Affected	Annoyed
100	0.26	0.67	0	0	0.28	0.73	0	0	0.28	0.73	0	0
95	0.52	1.35	0	0	0.50	1.30	0	0	0.51	1.33	0	0
90	1.04	2.71	0	0	0.82	2.13	0	0	1.01	2.60	0	0
85	1.83	4.73	0	0	1.45	3.75	0	0	1.63	4.22	0	0
80	3.29	8.52	293	3	2.77	7.17	706	12	2.67	6.92	0	0

*NOTE: Population affected and/or annoyed is zero for all three above flight procedures when operating from Runway 18.

using the standard flight procedure are shown in Figure 5-73. As in the case of the EBF airplane, the 100 and 95 EPNdB footprints are essentially contained within the airport boundary. The takeoff lobe of the 85 and 80 EPNdB footprints impact on the populated areas of Upper Newport Bay to a greater extent than the comparable footprints of the EBF airplane.

Low-Impact Procedure. The single event noise footprints of the low-impact procedure are shown in Figure 5-74. The power cutback of this straight flight path procedure reduces the impact in the Upper Newport Bay area but increases the impact of the 85 EPNdB takeoff lobe upon the East Bluff development in the Middle Bay area.

Minimum-Impact Procedure. A total of fifteen different takeoff techniques were evaluated. The minimum-impact procedure shown in Figure 5-75 involves initiating flap retraction at 250 feet (76 m) altitude and a power cutback to 66 percent gross takeoff thrust at 500 feet (152 m) followed by a 20 degree (0.349 radian) turn to the left initiated at an altitude of 650 feet (198 m). As shown in Figure 5-76 the turn positions the flight path over the center portion of Upper Newport Bay. The early power cutback significantly reduces the sideline impact at the south end of the airport. The 80 EPNdB takeoff spike extends over the populated section of the East Bluff area but unlike the 80 EPNdB spike of the EBF airplane closes before reaching Balboa Island.

A summary of the community impact evaluation of the standard, low-impact, and minimum-impact flight procedures for the M-150-4000 airplane at Orange County Airport is presented in Table 5-14. The low-impact procedure provided a 39 percent reduction in number of people highly annoyed compared to the standard or baseline procedure. An additional 5 percent reduction

NOISE FOOTPRINTS — STANDARD FLIGHT PROCEDURE
ORANGE COUNTY AIRPORT, RWY 19R — M·150·4000 AIRPLANE

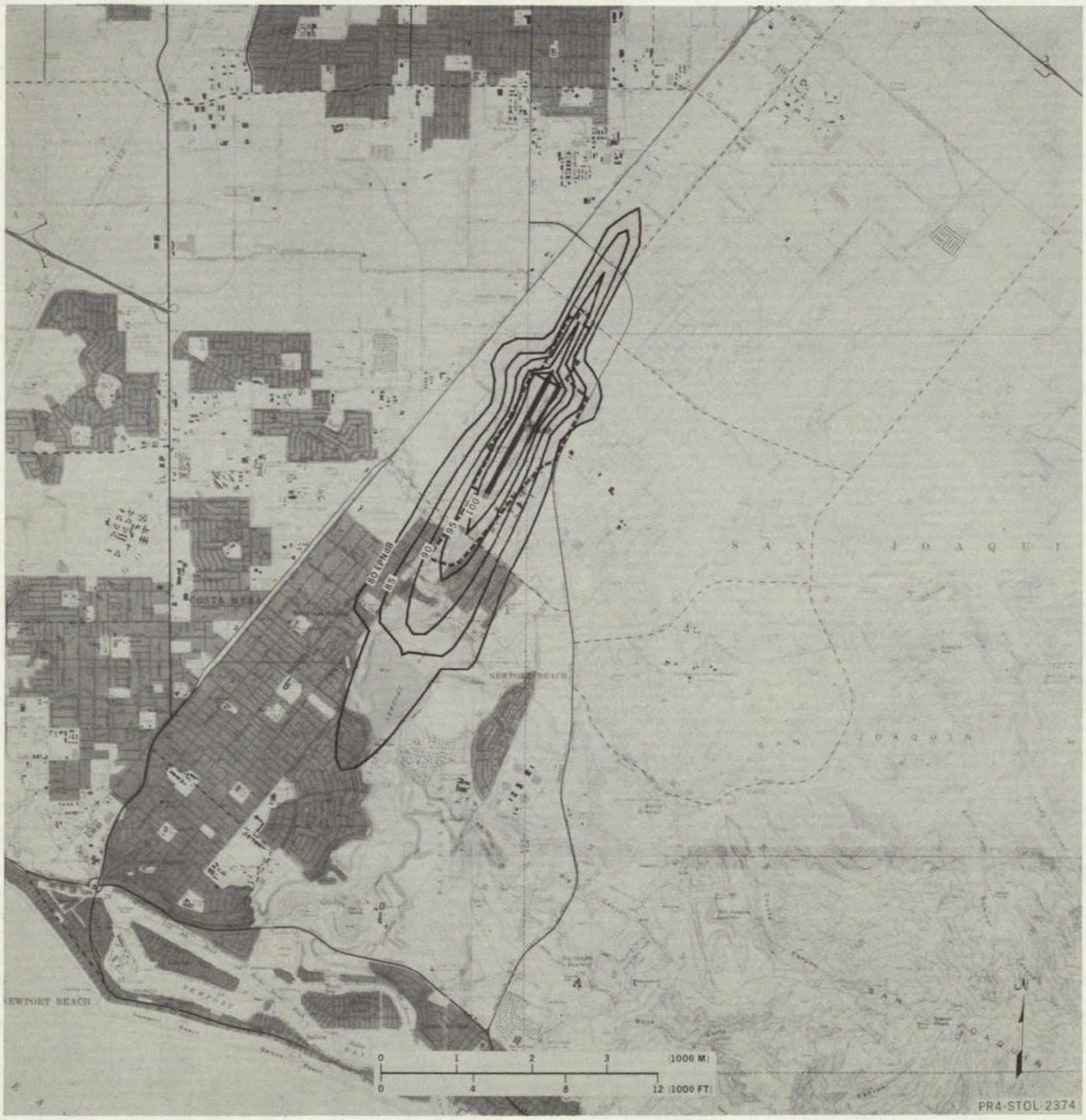


FIGURE 5-73.

NOISE FOOTPRINTS — LOW-IMPACT PROCEDURE
ORANGE COUNTY AIRPORT, RWY 19R — M·150·4000 AIRPLANE

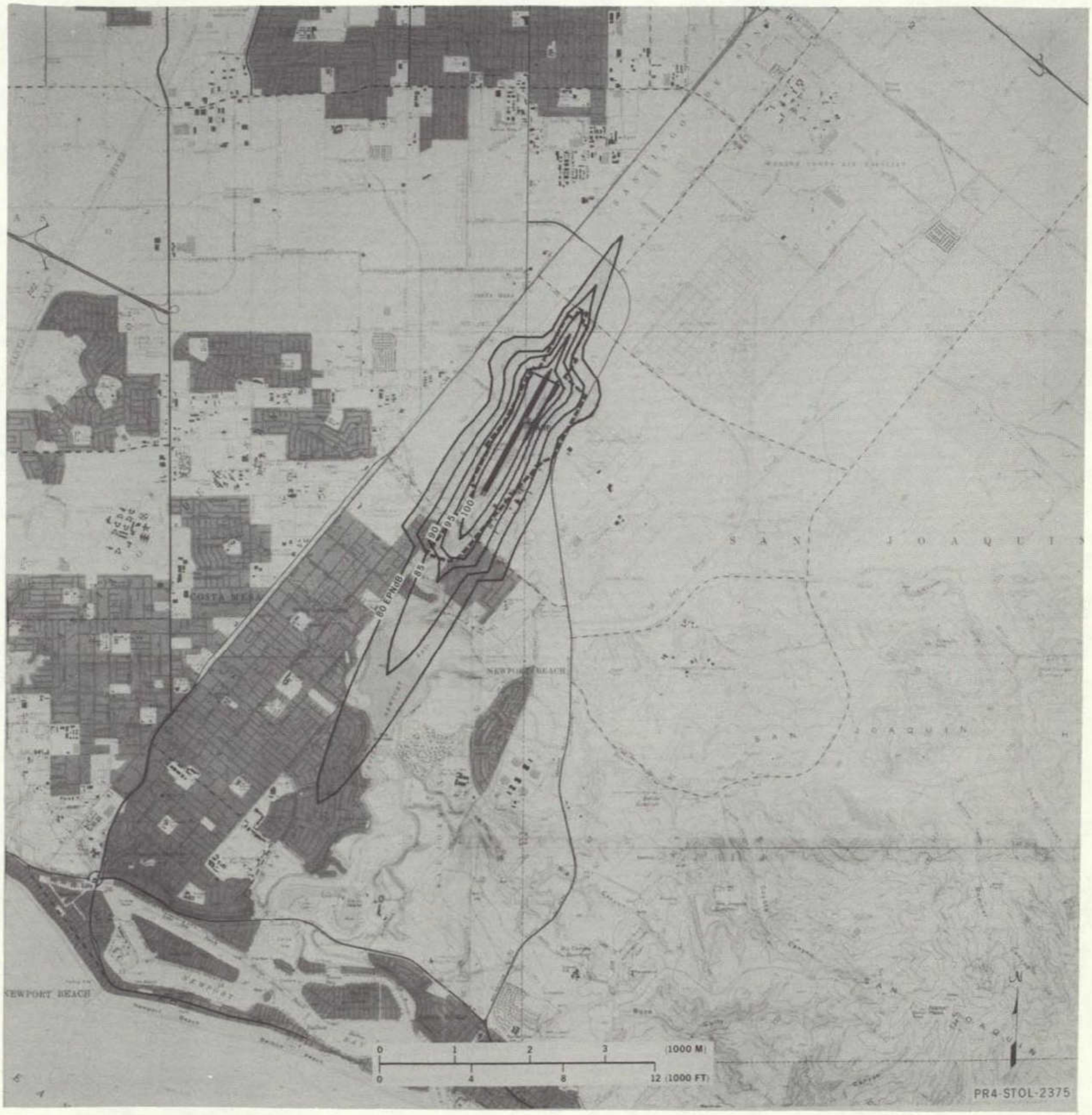


FIGURE 5-74.

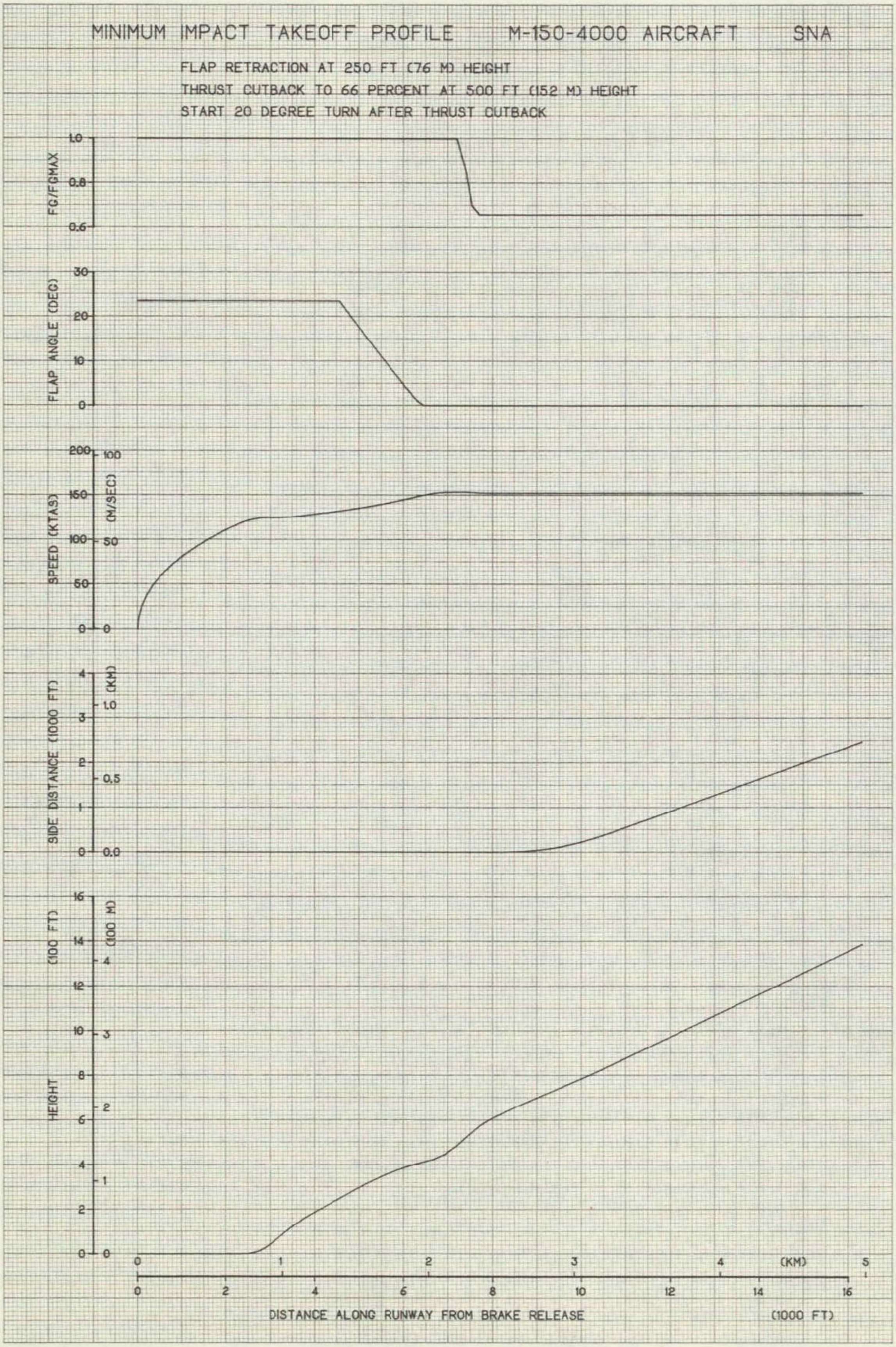

MINIMUM IMPACT TAKEOFF PROFILE M-150-4000 AIRCRAFT SNA
FLAP RETRACTION AT 250 FT (76 M) HEIGHT
THRUST CUTBACK TO 66 PERCENT AT 500 FT (152 M) HEIGHT
START 20 DEGREE TURN AFTER THRUST CUTBACK
FG/FGMAX
FLAP ANGLE (DEG)
SPEED (KTAS)
(M/SEC)
SIDE DISTANCE (1000 FT)
(KM)
HEIGHT (100 FT)
(100 M)
(KM)
DISTANCE ALONG RUNWAY FROM BRAKE RELEASE
(1000 FT)

FIGURE 5-75.

NOISE FOOTPRINTS — MINIMUM IMPACT PROCEDURE
ORANGE COUNTY AIRPORT, RWY 19R — M•150•4000 AIRPLANE

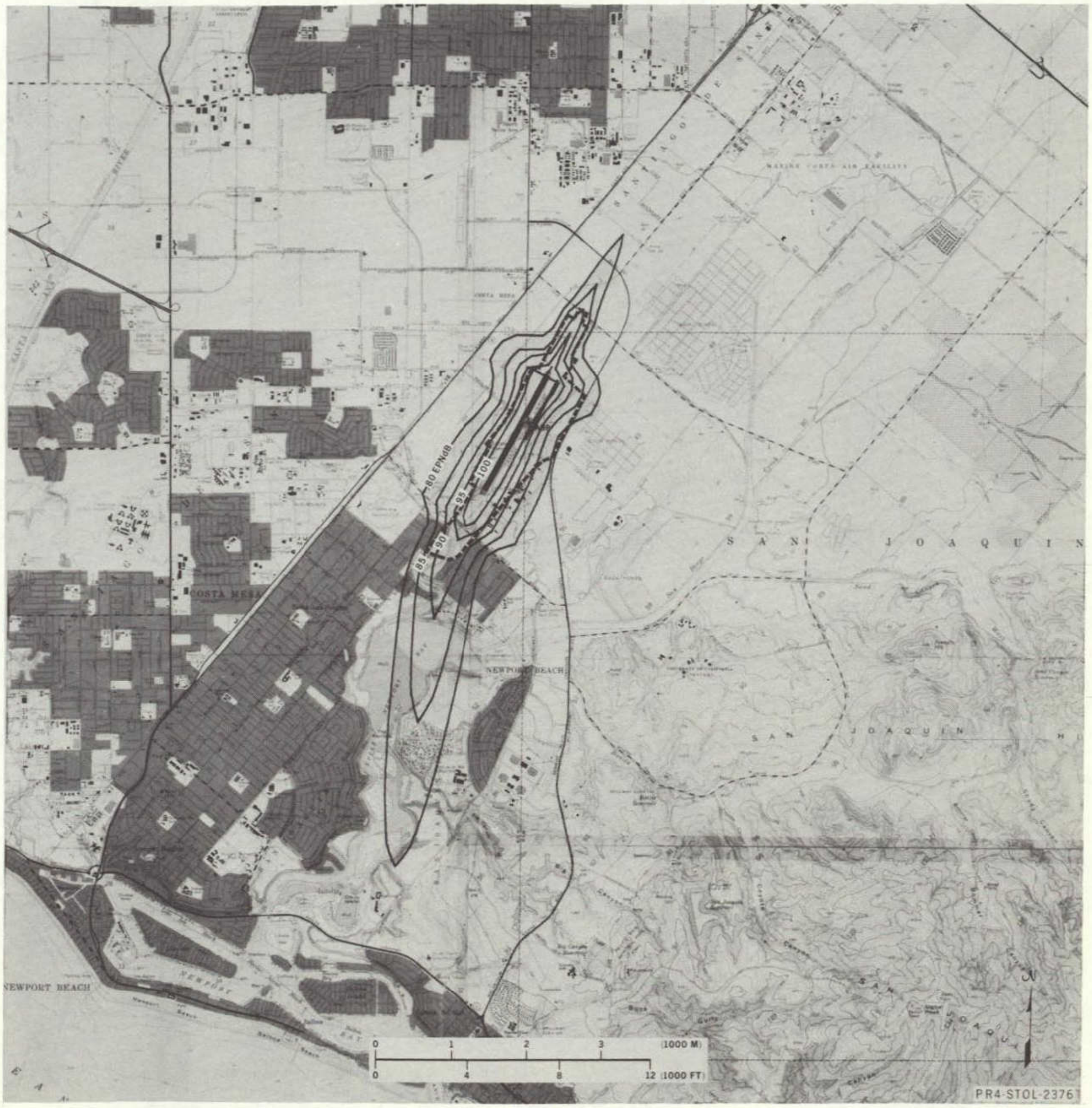


FIGURE 5-76.

TABLE 5-14

NOISE IMPACT SUMMARY - M.150.4000 AIRPLANE

ORANGE COUNTY AIRPORT - RUNWAY 19R

EPNL Contour	STANDARD PROCEDURE				LOW-IMPACT PROCEDURE				MINIMUM-IMPACT PROCEDURE			
	Contour Area		Population		Contour Area		Population		Contour Area		Population	
	Sq.Mi.	Sq.Km.	Affected	Annoyed	Sq.Mi.	Sq.Km.	Affected	Annoyed	Sq.Mi.	Sq.Km.	Affected	Annoyed
100	0.26	0.67	7	4	0.28	0.73	102	42	0.27	0.69	39	17
95	0.52	1.35	392	136	0.50	1.30	297	110	0.43	1.12	139	52
90	1.04	2.71	1192	336	0.82	2.13	656	199	0.82	2.11	713	188
85	1.83	4.73	2627	548	1.45	3.75	1513	324	1.51	3.90	1606	323
80	3.29	8.52	5349	655	2.77	7.17	3760	402	2.84	7.37	2516	364

was obtained with the minimum-impact procedure for a total reduction of 44 percent over the baseline case.

5.6.6.4 Noise Impact - CHICAGO MIDWAY - The community noise impact evaluation of the standard, low-impact, and minimum-impact flight operational techniques of the M-150-4000 airplane on Runways 22L and 31L at Chicago's Midway Airport is discussed below.

Standard Procedure. The single-event noise footprints using the standard operating technique are shown in Figure 5-77. As in the case of the EBF airplane, a small portion of the 100 EPNdB approach and takeoff lobes projects slightly into the populated areas at both ends of each runway.

Low-Impact Procedure. The single-event noise footprints of the low-impact procedure on both runways are shown in Figure 5-78. As noted, the 80 EPNdB takeoff lobe spike projects beyond the industrial areas of Stickney and Bedford Park and extends into the residential areas beyond.

Minimum-Impact Procedure. A total of seventeen different takeoff flight techniques were evaluated at each runway. The flight procedure which resulted in minimum impact when operating from Runway 22 is described in Figure 5-79. This procedure involved retracting the landing flaps at an altitude of 300 feet (91 m) and reducing power to 66 percent gross takeoff thrust at 500 feet (152 m) altitude. A 45 degree (.785 radian) turn to the right subsequently was initiated at an altitude of 600 feet (183 m) to direct the flight path over the unpopulated rail classification yards near Bedford Park southwest of the airport as shown in Figure 5-80. The one school contained within the footprint impact area is exposed to a noise level of approximately 90 EPNdB on takeoff.

NOISE FOOTPRINTS — STANDARD FLIGHT PROCEDURE
MIDWAY AIRPORT, RWS 22L, 31L — M·150·4000 AIRPLANE

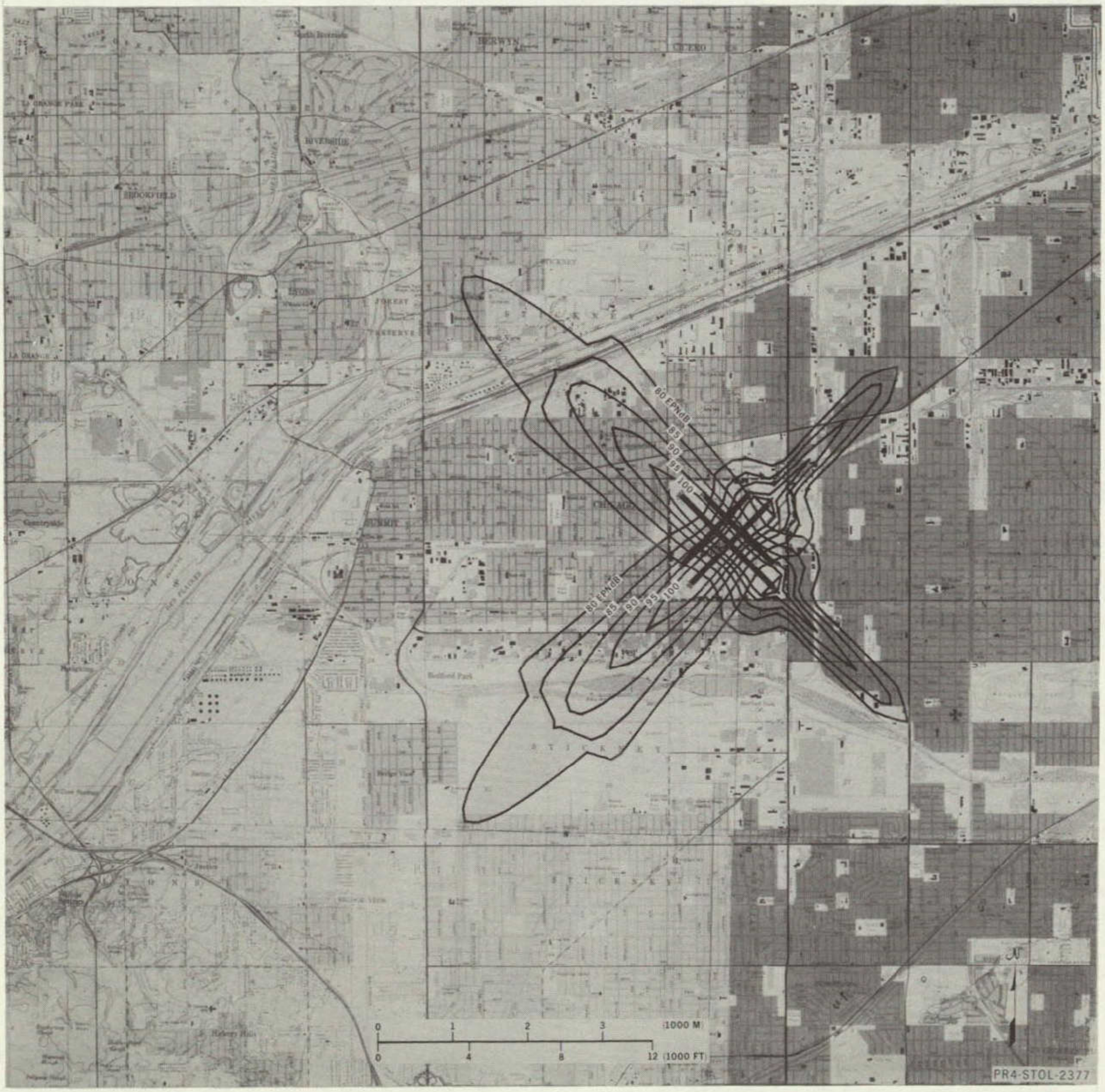


FIGURE 5-77.

NOISE FOOTPRINTS — LOW-IMPACT PROCEDURE
MIDWAY AIRPORT, RWS 22L, 31L — M 150 4000 AIRPLANE

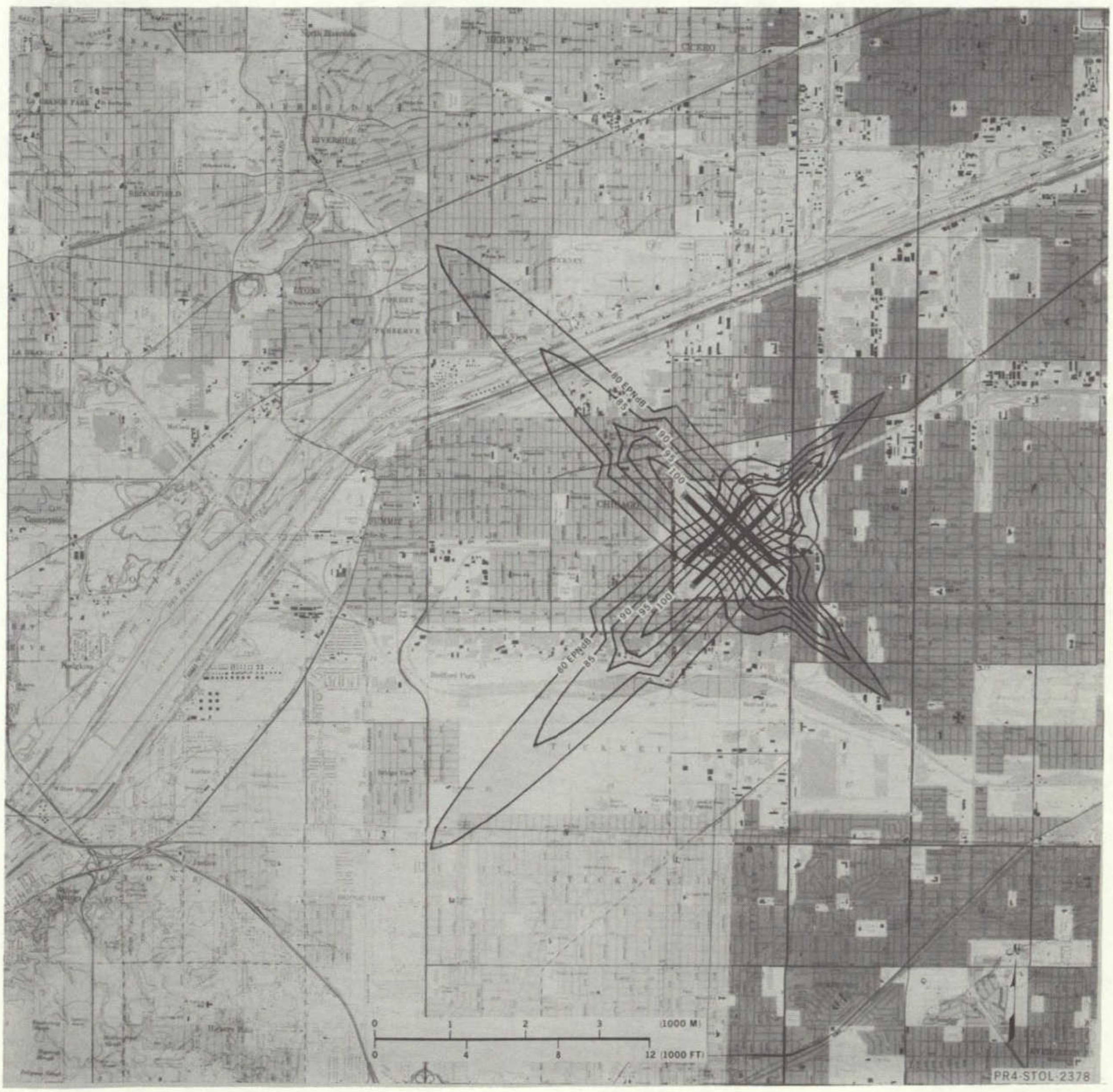


FIGURE 5-78.

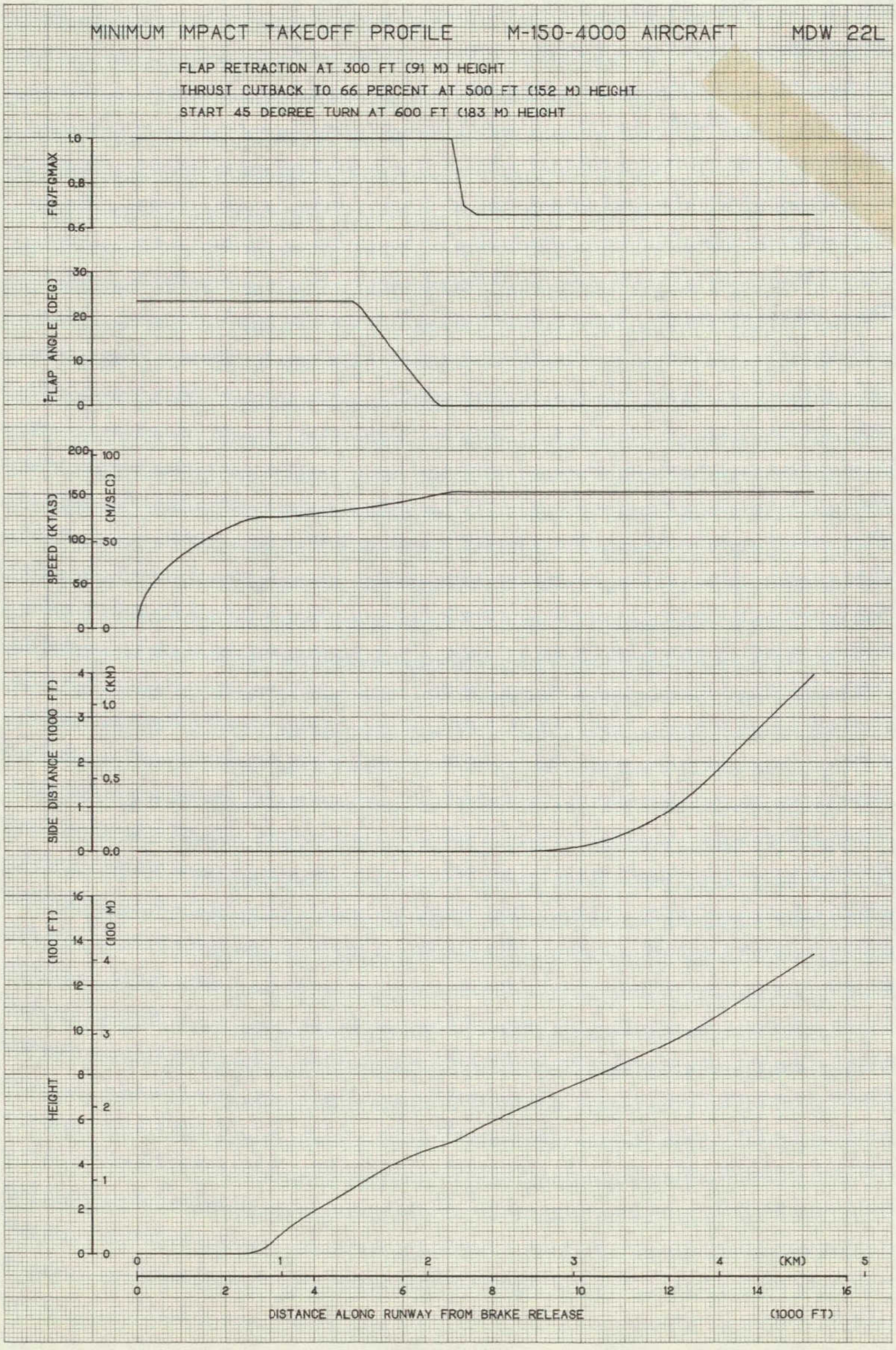

MINIMUM IMPACT TAKEOFF PROFILE M-150-4000 AIRCRAFT MDW 22L
FLAP RETRACTION AT 300 FT (91 M) HEIGHT
THRUST CUTBACK TO 66 PERCENT AT 500 FT (152 M) HEIGHT
START 45 DEGREE TURN AT 600 FT (183 M) HEIGHT
FG/FGMAX
FLAP ANGLE (DEG)
SPEED (KTAS)
(M/SEC)
SIDE DISTANCE (1000 FT)
(KM)
HEIGHT (100 FT)
(100 M)
DISTANCE ALONG RUNWAY FROM BRAKE RELEASE
(1000 FT)

FIGURE 5-79.

NOISE FOOTPRINTS — MINIMUM IMPACT PROCEDURE
MIDWAY AIRPORT, RWS 22L, 31L — M•150•4000 AIRPLANE

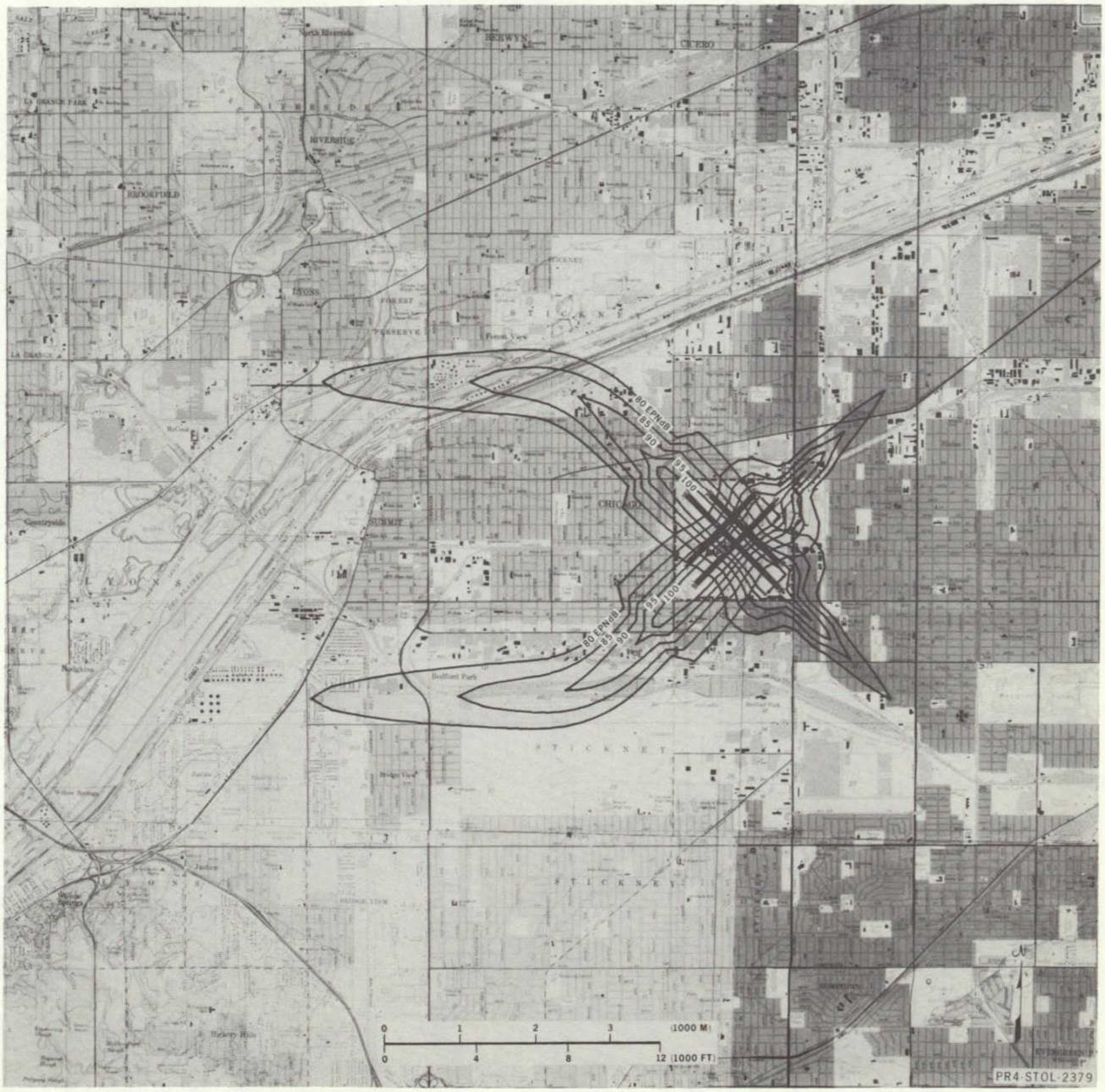


FIGURE 5-80.

A similar technique was used to arrive at a minimum-impact procedure for Runway 31L. The corresponding takeoff flight profile is described in Figure 5-81. The resultant noise footprints were shown in Figure 5-80. This procedure is similar to that used for the EBF airplane. Landing flap retraction was initiated at 300 feet (91 m) altitude and power subsequently was reduced to 66 percent gross takeoff thrust at an altitude of 500 feet (152 m). A 45 degree (.079 radian) right turn was initiated at 700 feet (213 m) altitude to direct the flight path over the unpopulated areas of the Southwest Expressway and Chicago ship canal. Four schools are impacted by this procedure, all to noise levels of less than 90 EPNdB during takeoff.

A summary of the community noise impact of the three procedures using Runway 22L is presented in Table 5-15. The low-impact procedure results in a 20 percent reduction in number of persons highly annoyed compared to the standard procedure. The minimum-impact procedure provides an additional reduction of 10 percent or a total reduction of 30 percent compared to the baseline.

A similar summary of the Runway 31L procedures is shown in Table 5-16. The low-impact procedure results in a 22 percent reduction in the number of persons highly annoyed compared to the baseline procedure. The minimum-impact technique provides an additional 9 percent reduction, or a total reduction of 31 percent over the standard procedure when operating from Runway 31L.

5.6.7 Summary of Results - The primary objective of the community noise impact evaluation was to demonstrate that aircraft noise can be reduced by flight operational techniques tailored to a specific aircraft and airport.

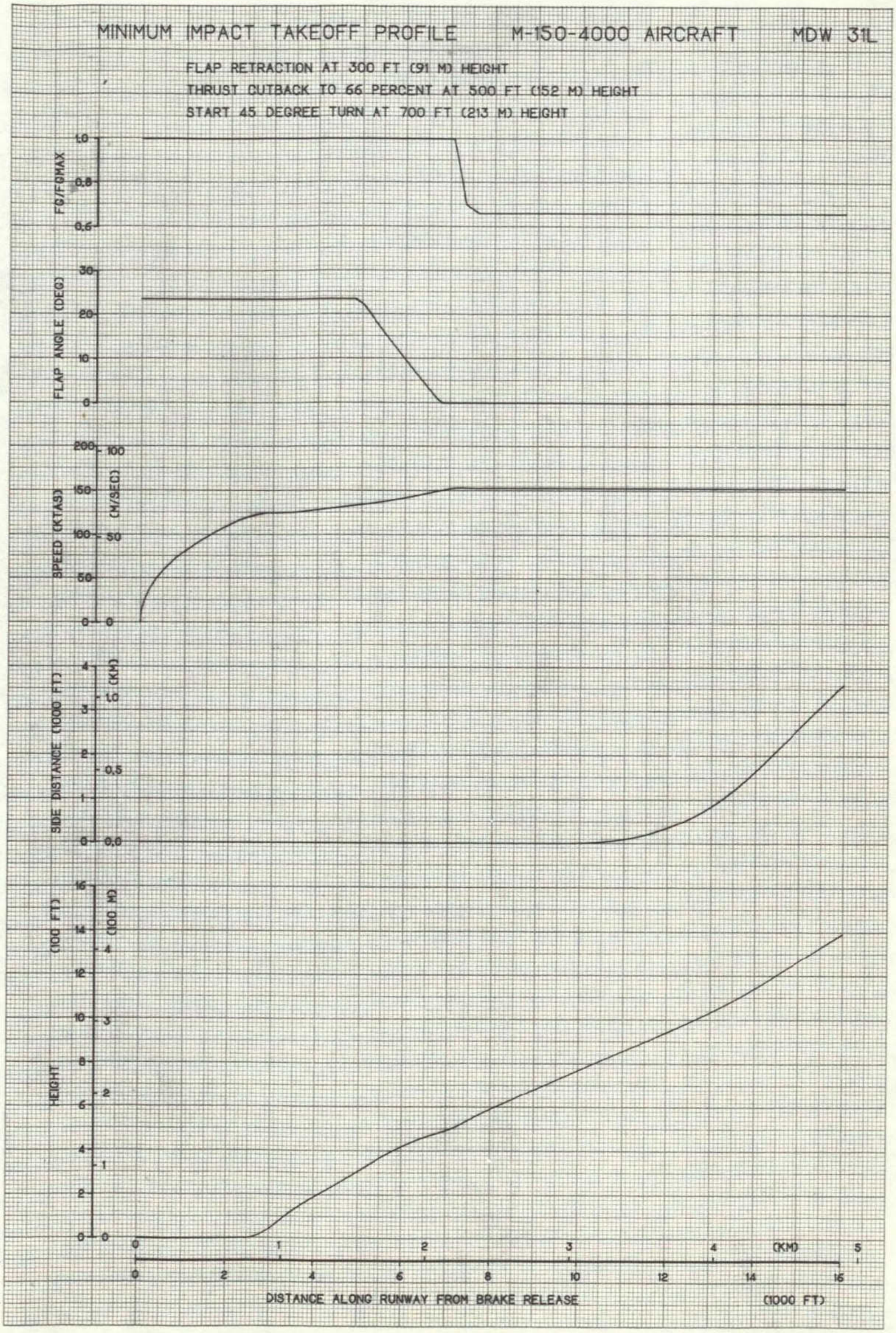

MINIMUM IMPACT TAKEOFF PROFILE M-150-4000 AIRCRAFT MDW 31L
FLAP RETRACTION AT 300 FT (91 M) HEIGHT
THRUST CUTBACK TO 66 PERCENT AT 500 FT (152 M) HEIGHT
START 45 DEGREE TURN AT 700 FT (213 M) HEIGHT
FG/FGMAX
FLAP ANGLE (DEG)
SPEED (KTAS)
(M/SEC)
SIDE DISTANCE (1000 FT)
(KM)
HEIGHT (100 FT)
(100 M)
DISTANCE ALONG RUNWAY FROM BRAKE RELEASE
(KM)
(1000 FT)

FIGURE 5-81.

TABLE 5-15

NOISE IMPACT SUMMARY - M.150.4000 AIRPLANE

MIDWAY AIRPORT - RUNWAY 22L

EPNL Contour	STANDARD PROCEDURE				LOW-IMPACT PROCEDURE				MINIMUM-IMPACT PROCEDURE			
	Contour Area		Population		Contour Area		Population		Contour Area		Population	
	Sq.Mi.	Sq.Km.	Affected	Annoyed	Sq.Mi.	Sq.Km.	Affected	Annoyed	Sq.Mi.	Sq.Km.	Affected	Annoyed
100	0.26	0.67	263	108	0.28	0.73	538	277	0.26	0.68	400	168
95	0.52	1.35	1703	616	0.50	1.30	1608	612	0.42	1.09	1196	442
90	1.04	2.71	3034	962	0.82	2.13	2681	896	0.82	2.14	2406	753
85	1.83	4.73	6496	1478	1.45	3.75	4862	1218	1.54	3.98	4317	1040
80	3.29	8.52	11352	1686	2.77	7.17	9008	1354	2.89	7.50	8247	1178

TABLE 5-16

NOISE IMPACT SUMMARY - M.150.4000 AIRPLANE

MIDWAY AIRPORT - RUNWAY 31L

EPNL Contour	STANDARD PROCEDURE				LOW-IMPACT PROCEDURE				MINIMUM-IMPACT PROCEDURE			
	Contour Area		Population		Contour Area		Population		Contour Area		Population	
	Sq.Mi.	Sq.Km.	Affected	Annoyed	Sq.Mi.	Sq.Km.	Affected	Annoyed	Sq.Mi.	Sq.Km.	Affected	Annoyed
100	0.26	0.67	202	84	0.28	0.73	405	172	0.26	0.68	202	87
95	0.52	1.35	1653	587	0.50	1.30	1451	540	0.42	1.09	844	314
90	1.04	2.71	5307	1496	0.82	2.13	3609	1069	0.82	2.12	3204	899
85	1.83	4.73	8973	2004	1.45	3.75	6458	1490	1.54	3.98	6136	1328
80	3.29	8.52	14413	2253	2.77	7.17	12482	1764	2.89	7.50	10554	1549

A secondary objective was the development of an effective methodology or tool for assessing aircraft noise impact on the airport and adjacent community. The study accomplished both objectives -- to an even greater degree than anticipated.

The community noise impact evaluation investigated the noise impact of two different types of short-haul turbofan-powered aircraft at four representative airports: Hanscom Field, Washington National, Orange County and Chicago Midway. All have existing noise problems ranging from severe to moderate. The aircraft types were the E-150-3000, a 150-passenger externally-blown-flap (EBF) four-engine airplane designed for a 3000-foot (914 m) field length, and a 150-passenger mechanical-flap (MF) two-engine aircraft designed for a 4000-foot field length. The takeoff design noise levels of the two airplanes were 97 EPNdB at 500 foot (152 m) sideline for the EBF and 101 EPNdB for the MF airplane.

EBF Airplane. Results of the community noise evaluation of the E-150-3000 airplane are summarized in Table 5-17. The criteria for the evaluation was the total number of persons highly annoyed within the single-event 80 EPNdB noise footprint. The relationship between the number of persons affected or exposed and the number of persons highly annoyed was based on a relationship established by the U.S. Department of Transportation. The evaluation showed that an average reduction of approximately 40 percent in the number of persons highly annoyed could be achieved by varying flight operational procedures. All procedures investigated are considered to be well within safe operating limits and should involve no compromise in flight safety. Acceptability of the procedures, however, must be determined by actual

TABLE 5-17

NOISE REDUCTION SUMMARY

E.150.3000 AIRPLANE

AIRPORT	NUMBER OF PERSONS HIGHLY ANNOYED				
	Standard Procedure	Low-Impact Procedure	Reduction From Std.	Min.-Impact Procedure	Reduction From Std.
BED - HANSCOM FIELD					
Runway 5	297	190	36%	188	37%
DCA - WASHINGTON NATIONAL					
Runway 36	9	30*	(333%)	0	100%
Runway 18	0	0	-	0	-
SNA - ORANGE COUNTY					
Runway 19R	468	324	31%	282	40%
MDW - CHICAGO MIDWAY					
Runway 22L	1819	1117	39%	997	45%
Runway 31L	2168	1619	25%	1322	39%

* The increase from the standard procedure results from a lower power cutback height which extends the 80 and 85 EPNdB contours over highly populated areas.

flight tests. Approximately two-thirds of the noise reduction was achieved through a parametric analysis of the various techniques which assumed a uniform population distribution. The remaining third was achieved by tailoring the flight techniques and aircraft flight paths to a specific airport.

EBF With 10 Percent Oversized Engines. The study also investigated the amount of community noise reduction achievable by the E-150-3000 airplane with 10 percent oversized engines. This evaluation was conducted at Chicago Midway, which has the highest population concentration of the four study airports. The results of this evaluation are summarized in Table 5-18. The oversized engine aircraft provided an approximate 8 percent reduction in number of persons highly annoyed compared to the basic E-150-3000 airplane.

MF Airplane. Results of the community noise evaluation of the M-150-4000 airplane are summarized in Table 5-19. Evaluation criteria were identical to those used for the E-150-3000. As with the EBF airplane, the major part of the reduction resulted from the acoustic parametric analysis. Approximately 6 percent of the total reduction was obtained by tailoring the takeoff flight procedure to the specific airport community situation.

It should be noted that the two aircraft designs -- the E-150-3000 and the M-150-4000 are not directly comparable since they have different takeoff noise levels and field lengths. The study did demonstrate that the use of flight operational procedures to minimize noise impact was equally applicable to each aircraft type; however, the operational procedures varied slightly due to differences in aircraft performance characteristics.

Table 5-18

NOISE REDUCTION COMPARISON

E.150.3000 VS. E.150.3000 WITH 10% OVERSIZED ENGINES

MIDWAY AIRPORT

RUNWAY	NUMBER OF PERSONS HIGHLY ANNOYED		
	E.150.3000	10% Oversized Engines	Impact Reduction
MDW - RUNWAY 22L			
Standard Procedure	1819	1776	2.4%
Minimum-Impact Procedure	997	903	9.1%
MDW - RUNWAY 31L			
Standard Procedure	2168	2032	6.3%
Minimum-Impact Procedure	1322	1236	6.5%

Table 5-19

NOISE REDUCTION SUMMARY

M.150.4000 AIRPLANE

AIRPORT	NUMBER OF PERSONS HIGHLY ANNOYED				
	Standard Procedure	Low-Impact Procedure	Reduction From Std.	Min.-Impact Procedure	Reduction From Std.
BED - HANSCOM FIELD					
Runway 5	361	243	33%	243	33%
DCA - WASHINGTON NATIONAL					
Runway 36	3	12*	(400%)	0	100%
Runway 18	0	0	-	0	-
SNA - ORANGE COUNTY					
Runway 19R	655	402	39%	364	44%
MDW - CHICAGO MIDWAY					
Runway 22L	1686	1354	20%	1178	30%
Runway 31L	2253	1764	22%	1549	31%

* The increase from the standard procedure results from a lower power cutback height which extends the 80 and 85 EPNdB contours over highly populated areas.

Airport Comparison. Figures 5-82 and 5-83 compare both the number of persons affected or exposed, and the number of persons highly annoyed for each airport and runway combination. The greatest noise impact is experienced at Chicago Midway and the least at Washington National.

Noise Evaluation Methodology. The evaluation procedures and methodology developed in this study provide an effective tool for determining aircraft noise impact upon the airport community. Much work remains to be done, however, to develop more accurate aircraft noise prediction methods and to standardize airport noise evaluation methodology.

AIRPORT NOISE IMPACT SUMMARY

E.150.3000 AIRPLANE

80 EPNdB Noise Footprint

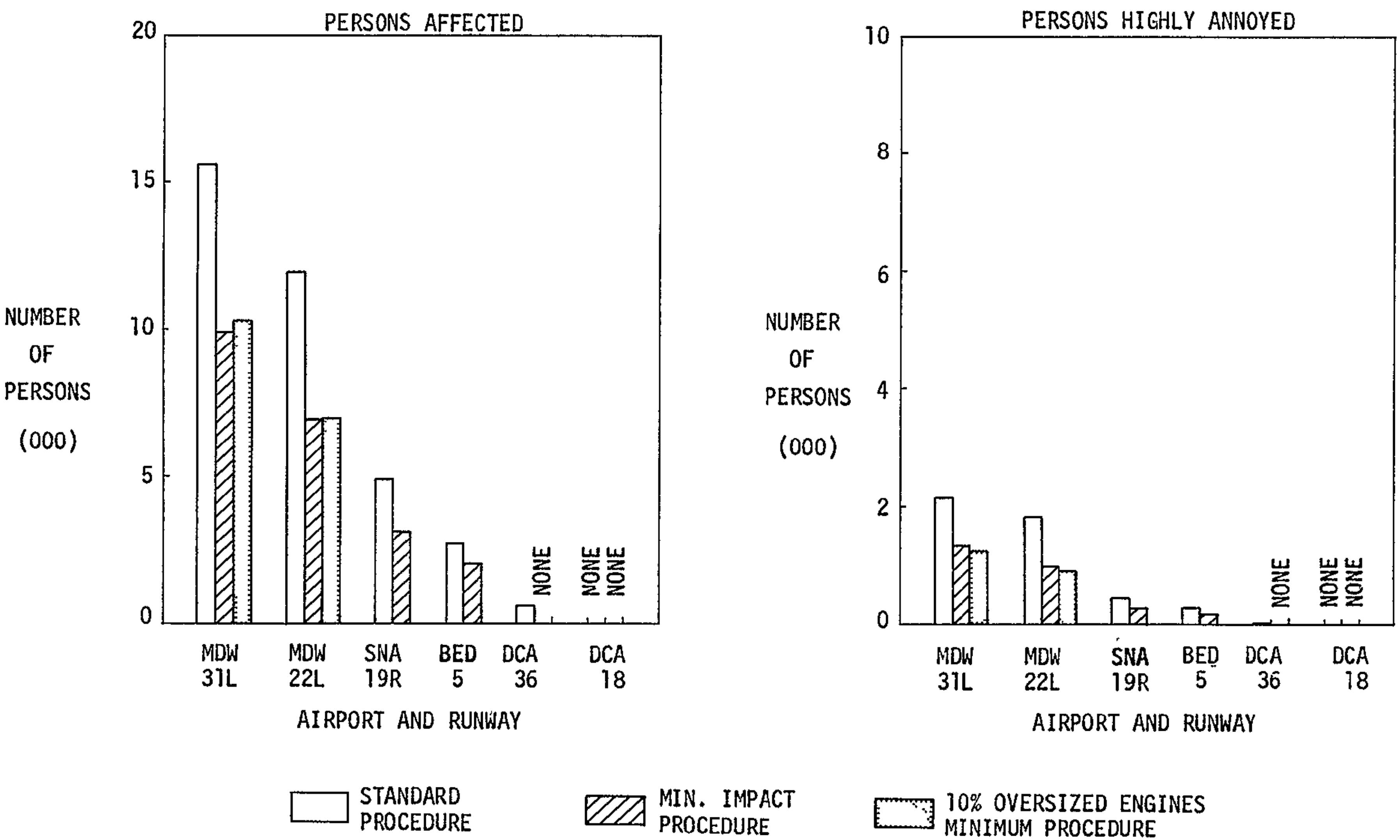


FIGURE 5-82.

AIRPORT NOISE IMPACT SUMMARY

M.150.4000 AIRPLANE

80 EPNdB NOISE FOOTPRINT

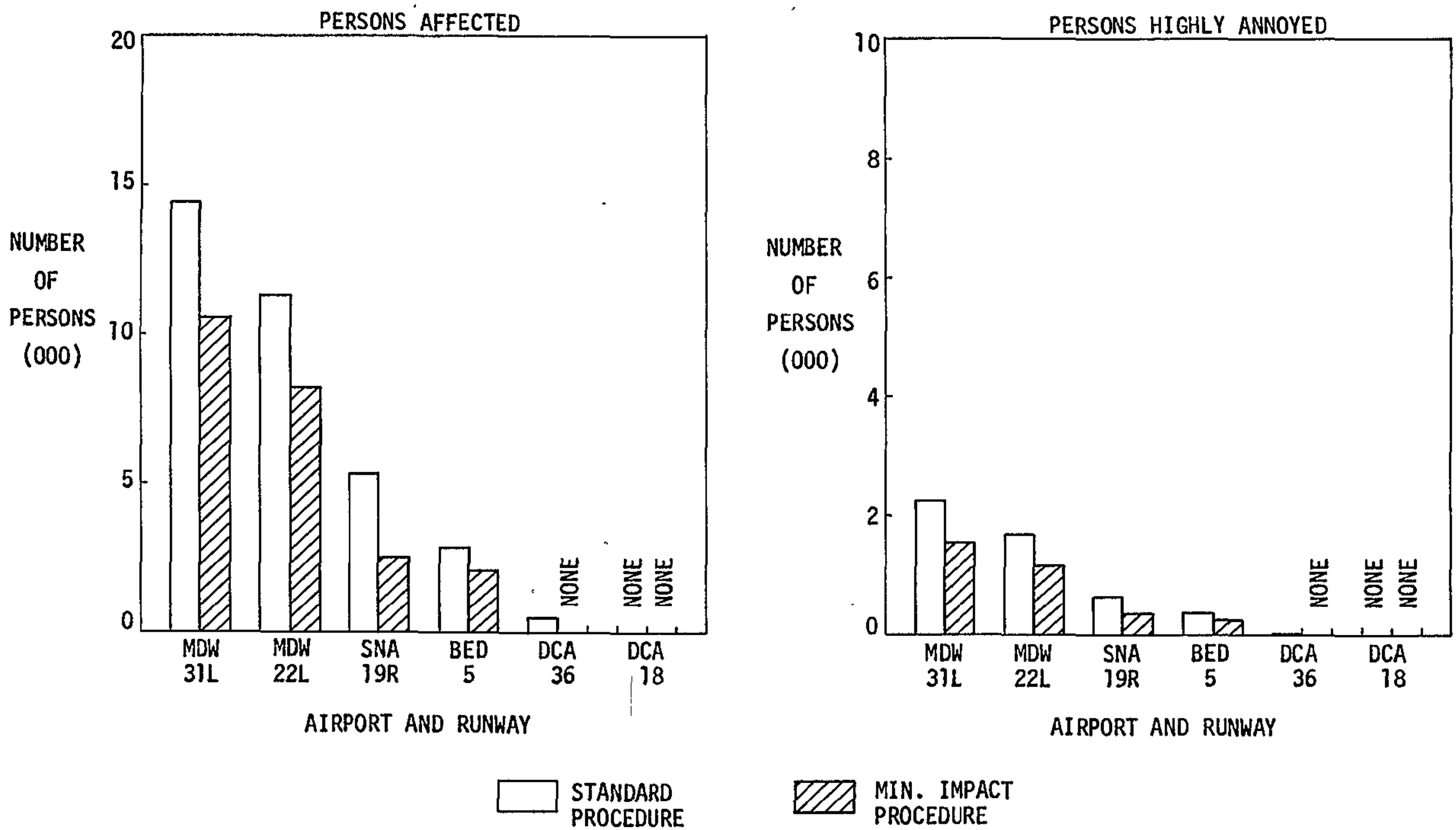


FIGURE 5-83.

6.0 CONCLUSIONS AND RECOMMENDATIONS

It has been shown that aircraft operational techniques can significantly reduce airport community noise. The aircraft studied were designed for field lengths of 3000 feet (914 m) and 4000 feet (1200 m) but the methodologies described herein are applicable to all fixed-wing aircraft. The following are conclusions drawn from this study:

Conclusions:

(1) Over the range considered, some DOC decrease can be obtained at the expense of increased noise level by using engines with a higher fan pressure ratio.

(2) Acoustical treatment of engine inlet and exhaust ducts, without an increase in dimensions, provides some reduction in noise with little or no increase in DOC.

(3) A variable-pitch engine with a fan pressure ratio of 1.32 results in an aircraft with a lower TOGW than one with a 1.57 FPR fixed-pitch fan. A 1.32 FPR engine results in a higher DOC because of the slower cruise speed resulting from its lower cruise thrust. Higher fuel prices will decrease the slight DOC advantage of the 1.57 FPR engine. Increasing the fan pressure ratio of a variable-pitch fan while maintaining the capability of operating in the reverse mode will increase cruise thrust. This may reduce operating costs by improved productivity resulting from higher cruise speeds.

(4) For a MF installation, the bypass ratio of the engine can be controlled so that the primary jet noise will have little effect on the total propulsion system noise level.

(5) For a field length of 3000 feet (914 m) there is very little difference between a two- and four-engine MF aircraft configuration in terms of direct operating cost. Higher fuel prices will tend to favor the four-engine configuration due to its lower total installed thrust when sized by field length performance.

(6) The trade study for the E-150-3000 aircraft with 1.25 FPR engines showed that there was very little difference in DOC between an optimum wing geometry and that used in the STOL System Study. Changing to an optimum wing geometry (primarily a reduction in wing sweep) would result in approximately a one percent reduction in DOC. The insensitivity to wing geometry is due in part to the aircraft sizing philosophy: the engine is selected for a field length and sideline noise requirement rather than a cruise speed requirement.

(7) The use of engines larger than required to meet field length requirements for an E-150-3000 type aircraft can result in a reduction in community noise impact due to the higher climb gradients and lower allowable takeoff flap angles. There is essentially no increase in DOC for engine over-sizing of less than 10 percent, but there is a fuel consumption penalty. Desirable engine size increases would probably be less than 10 percent. It appears that a similar result would be found for mechanical-flap aircraft.

(8) For both the EBF and MF aircraft, a decelerating approach procedure produced the smallest noise impact for all of the approach techniques examined. Two-segment approaches and turning approach paths do not provide any gains for low noise aircraft since the 80 EPNdB noise level, the lower limit of the selected annoyance criteria, corresponds

to an aircraft height of approximately 500 feet, a height by which all configuration or path changes should be complete. The lower the aircraft noise level, the less the potential gains on the landing approach due to operational techniques.

(9) Significant reductions in airport community noise impact were achieved by using results of parametric studies of landing and takeoff flight operational techniques for a specific aircraft design.

(10) An additional reduction in community noise impact was achieved by tailoring the flight techniques to produce minimum impact at a specific airport and runway combination.

(11) A reduction in people highly annoyed of approximately 8 percent was achieved by the E-150-3000 with 10 percent oversized engines relative to the basic E-150-3000 airplane at the one airport examined.

(12) In general, the number of people exposed and/or annoyed by the 80 and 85 EPNdB footprints exceeded by a factor of two the number similarly affected by the 90, 95 and 100 footprints. This points out the necessity of investigating low noise levels in community aircraft noise impact evaluations.

(13) For the quiet short-haul aircraft examined, takeoff operational techniques offered more potential than landing operational techniques for reducing community noise impact.

(14) The evaluation procedures and methodology developed in this study provide a useful tool for determining aircraft noise impact upon an airport community.

Recommendations:

(1) In the MF acoustic trade study, the nacelles were designed for aerodynamic efficiency and the available duct area was acoustically treated for noise suppression. It is recommended, therefore, that the MF acoustic trade study be extended to determine the potential noise reduction that can be achieved by lengthening the duct and adding more acoustical treatment.

(2) A study using the methods described in this report should be conducted on current CTOL aircraft. Such an evaluation may provide significant noise reduction potential for existing aircraft.

(3) Installation of oversized engines should be given consideration in future STOL aircraft designs where noise is a major consideration.

(4) Investigation of low levels of noise should be included in future STOL short-haul aircraft community noise evaluations due to the relatively high percentage of the population exposed to the lower noise levels.

(5) The study showed that approximately three times the number of persons were impacted by the 80 EPNdB noise footprint at Chicago Midway compared to the Orange County Airport for a comparable aircraft type. Noise complaint records, however, indicate that far more persons are highly annoyed at Orange County than at Midway (Reference 1). Additional research and development should be conducted to determine relative weighting factors for all elements affecting annoyance. The assumptions and methodology used as a basis for acoustic evaluations need to be studied in more detail. Some areas which warrant further study are as follows:

   a) Addition of source noise levels on a PNL or EPNL basis does not account for the spectral or directional characteristics of the source noise.

b) EPNL vs distance maps are based on steady state, level flyovers and are not necessarily representative of takeoff and landing flight procedures.

c) Ground attenuation and fuselage shielding as defined by SAE ARP 1114 does not account for the spectral characteristics of the noise or the aircraft structural configuration.

d) A standard methodology for generating aircraft noise contours should be established.

e) The relationship of the percent people annoyed as used herein needs further study. It equates 80 EPNdB with zero annoyance, and does not take into account the number of operations, time of day, ambient noise conditions, land use, social class structure, etc.

f) Operational techniques for noise reduction should be studied at a greater number of airports.

(6) Operational techniques can also be used to compare flight procedures on the basis of fuel consumption as well as noise impact. A program is recommended for investigating minimum energy terminal area flight procedures.

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7.0 REFERENCES

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3. H. E. Helms, Quiet Clean STOL Experimental Engine Study Program - Task II, EDR 7610, Detroit Diesel Allison, Division of General Motors.

4. Simulation of Propulsion Engine Cycles, MDC A0387, Volume I and II, 1 April 1970.

5. Large, J. P., Estimating Aircraft Turbine Engine Costs, Rand Report RM-63841/1-PR, September 1970.

6. Allison EDR 7441, STOL Aircraft Quiet Clean Propulsion System Study, May 1972.

7. Allison EDR 7442, STOL Aircraft Quiet Clean Propulsion System Study, May 1972.

8. Allison EDR 7443, STOL Aircraft Quiet Clean Propulsion System Study, May 1972.

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APPENDIX A - AIRCRAFT

A.1 PERFORMANCE ANALYSIS METHODS AND GROUNDRULES

A.1.1 Aircraft Sizing. - The sizing process is illustrated by Figure A-1. Thrust-to-weight and wing loading combinations which satisfy the takeoff and landing field length requirements together with parametric weight data (OEW = f(TOGW, W/S, T/W)), installed thrust and fuel flow maps, and drag and tail sizing information are used as inputs to a computer program which performs the aircraft sizing calculations. The mission profile used for airplane sizing is shown in Figure A-2.

A.1.2 Takeoff. - STOL takeoff performance was estimated by calculating the time history of the takeoff flight path. This method allows for recognition of changes in aerodynamic characteristics and flight limitations which occur during the maneuver. The calculations are governed by the following assumptions:

1. The aircraft is assumed to be a point mass, i.e., second order rotational dynamics have been ignored and the analysis is essentially two dimensional.

2. The forces acting on the aircraft are summed in the longitudinal and normal directions and are a function of true airspeed, flight path angle, angle of attack and height above the ground.

3. Any restriction on speed, acceleration, attitude, etc., may be imposed as desired.

4. The path is generated by numerical integration of the forces acting on the aircraft over small increments in time using a digital computer.

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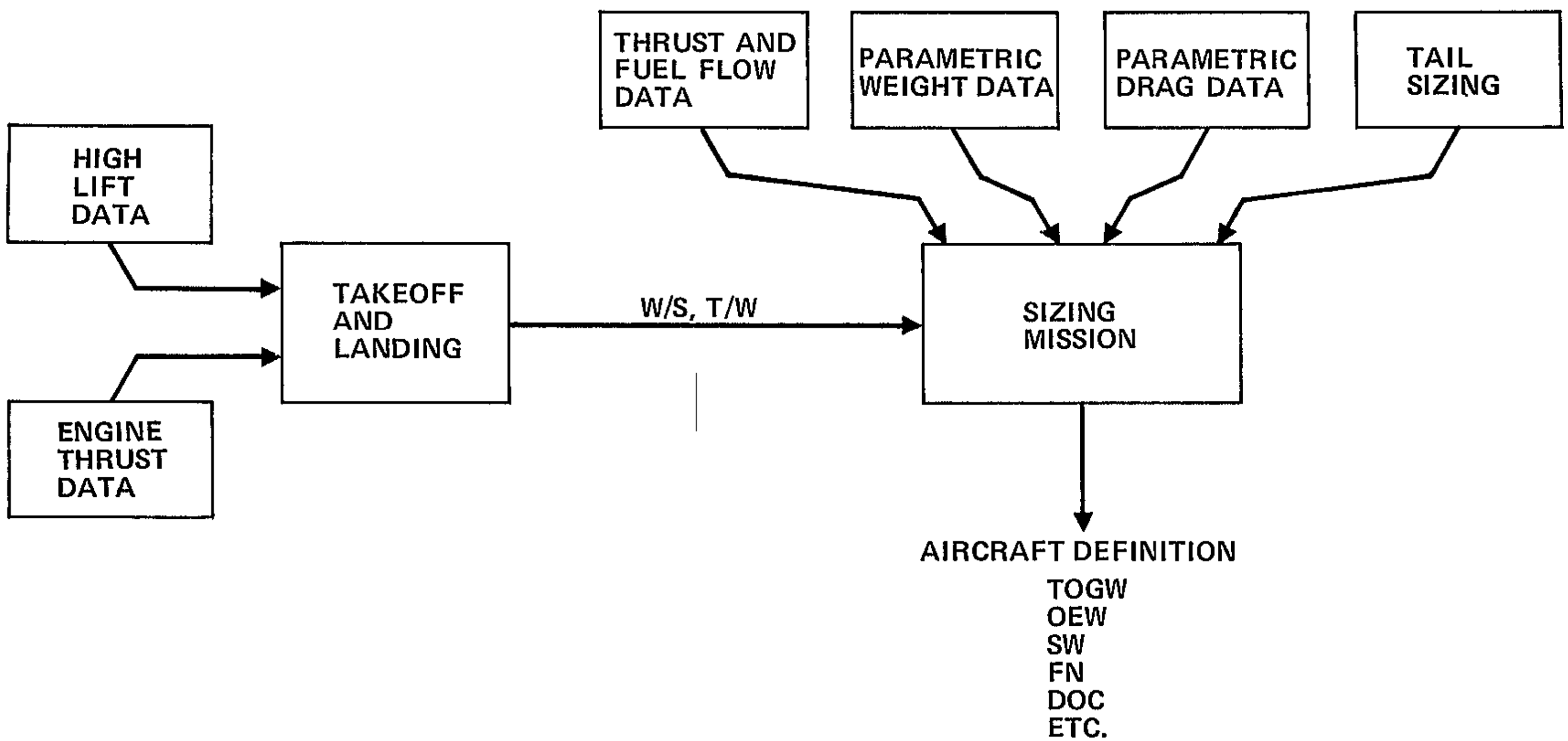
AIRCRAFT SIZING PROCESS



PR3-STOL-1495

FIGURE A-1.

SIZING MISSION PROFILE

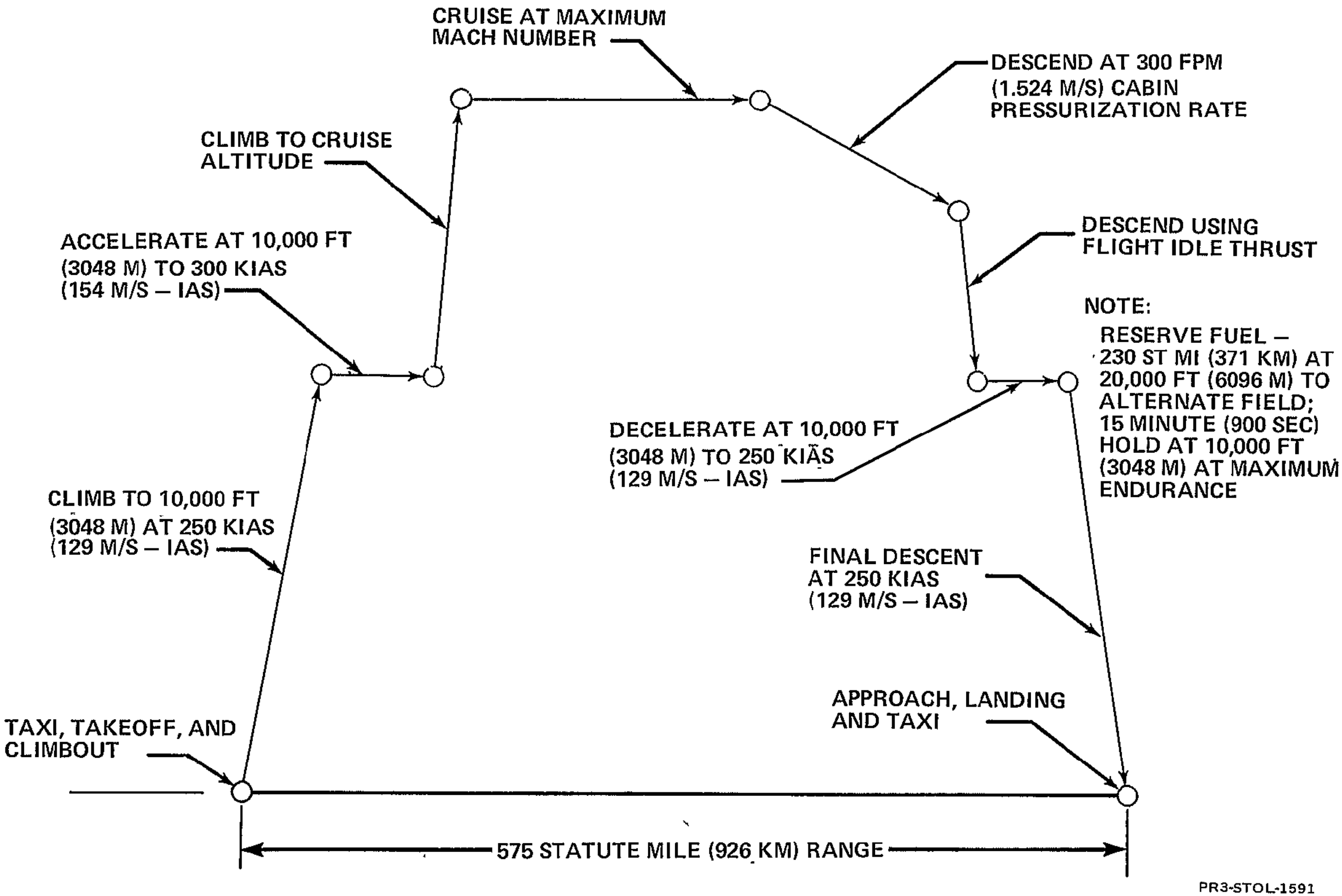


FIGURE A-2.

Based on FAR Part 25 requirements, takeoff field length was defined as the greater of:

1. 1.15 x all engine takeoff distance to 35 foot (10.7m) height.
2. Distance to 35 foot (10.7m) height with critical engine failure at V_1.
3. Distance to accelerate to V_1 and then decelerate to a stop.

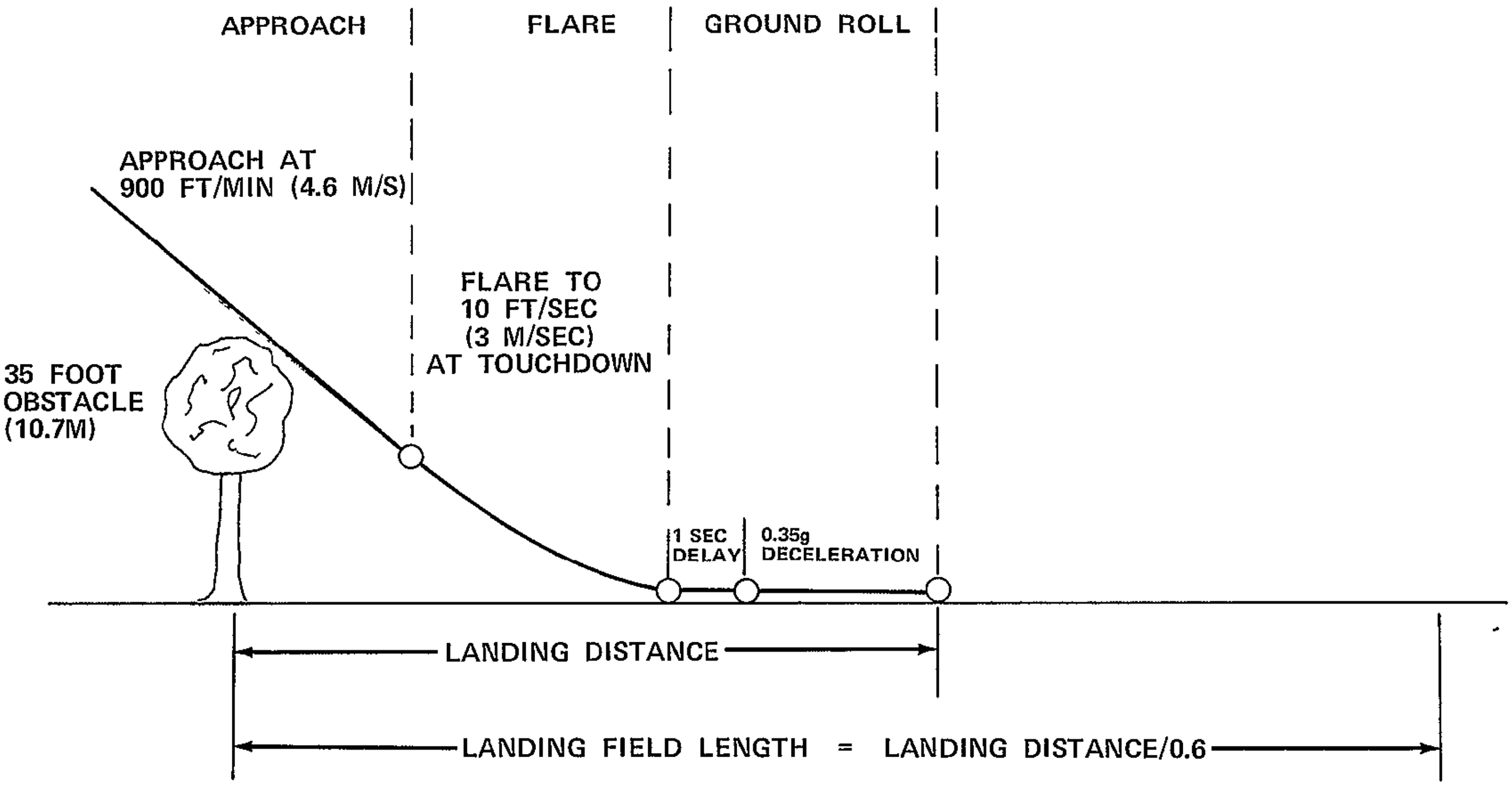
The following constraints were used in calculating the takeoff field lengths for the final design aircraft.

1. Rolling friction, $\mu = 0.025$
2. Fuselage angle of attack $\leq$ ground limit $= 15°$
3. Rotation rate, $\dot{\Theta} \leq 5°/sec$
4. $C_L \leq 90\%$ of CL_{max} out of ground effect
5. $C_L \leq 100\%$ of CL_{max} in ground effect
6. No deceleration during air run to 35 feet (10.7m) height
7. Five knot (2.57m/sec) early rotation may not give greater takeoff field length.
8. Accelerate-stop distance based on three second delay after reaching V_1 followed by a deceleration of 0.4g to a stop.
9. Second segment climb gradient (at V_2, with takeoff flap setting, critical engine inoperative, gear up and out of ground effect)

$$\geq \begin{cases} 3.0\% \text{ for four-engine aircraft} \\ 2.4\% \text{ for two-engine aircraft.} \end{cases}$$

A.1.3 Landing. - The methods and assumptions used in calculating landing field lengths are essentially the same as those used for takeoff performance. The landing maneuver consists of three segments; approach, flare and ground roll as shown in Figure A-3. Landing field length is defined as the landing distance over a 35-foot (10.7m) obstacle divided by a 0.6 factor, i.e., a 3000-foot

LANDING FIELD LENGTH DEFINITION



PR3-STOL-1494

FIGURE A-3.

(914 m) field length requires a landing distance of 1800 feet (549 m).

Approach margins at the landing flap setting, selected to provide adequate maneuver capabilities in the event of an engine failure, were a 1.33 available load factor for the externally-blown-flap aircraft and $1.3V_{min}$ margin for the mechanical-flap aircraft. These margins in addition to a 900 fpm (4.57 m/sec) approach sink rate define the approach conditions.

The flare maneuver is governed by the following constraints:

1. Fuselage angle of attack $\leq$ ground limit = 15^{o}
2. Rotation rate, $\leq 5^{o}$/sec
3. $C_L \leq 100\%$ of $C_{L_{max}}$ in ground effect.

For the externally-blown-flap aircraft, the flare maneuver was accomplished by retracting DLC spoilers at the flare height and rotating the aircraft at 5^{o}/second. Having no DLC capability, the mechanical-flap aircraft flare maneuver was performed by rotating the aircraft at 5^{o}/second starting at the flare height. As the aircraft approaches the ground, C_L and C_D tend to diminish due to ground effect.

The ground roll consists of one second at constant speed from touchdown to deceleration device effectiveness followed by a constant deceleration of 0.35g to a stop. Landing, like takeoff, was calculated for sea level, 95^{o}F (35^{o}C) conditions.

A.1.4 Mission. - The mission calculations, for the mission profile previously shown in Section A.1.1, Figure A-2, are performed in a computer program specifically developed by Douglas Aircraft Company during the last five years for the sizing of STOL aircraft in the advanced design stage. The methods used are essentially those of classical airplane performance. The computer program calculates 2 degrees-of-freedom mission time histories, iterating on weight, thrust, drag and tail sizing data to determine such characteristics as TOGW, wing area, engine size, OEW, fuel burned, etc. of an aircraft which satisfies the requirements of the mission profile with the desired payload. When a solution has been found, the program calculates a direct operating cost breakdown. Direct operating cost calculations were based on a production quantity of 300 aircraft with a 20 percent profit margin.

Cruise altitude and climb Mach number were optimized to minimize DOC. Mission performance was calculated for standard day conditions.

A.1.5 Flight Profile Calculations. - The methods and assumptions used in calculating the approach and takeoff flight profiles are essentially the same as used for the takeoff and landing calculations. A digital computer program is used to calculate the three degree-of-freedom time history of the flight path by numerical integration of the forces acting on the aircraft. The aircraft is assumed to be a point mass and the forces acting on it are summed in the horizontal x-y plane and normal direction. These forces are a function of true airspeed, flight path angle, angle of attack, bank angle and altitude. Engine thrust and ram drag are treated as a function of power setting, speed and altitude. Both conventional and powered lift aerodynamics may be handled.

The program is capable of recognizing changes in aircraft configuration such as gear drag, flap angle and DLC,etc., either as a step function or as a time variant function. Many limitations may be imposed on the calculations, i.e., limitations on attitude, angle of attack, power setting, stall speed margin, bank angle, etc. Calculations of turning flight paths include roll-in and roll-out bank angle changes. In addition, the program can be used to determine fuel used during terminal area maneuvers.

Program output consists of a listing of the time history, part of which is shown in Figure A-4 and a card deck which is used as input for the noise impact calculation program.

TIME DISTANCE HEIGHT	V(KTAS) V(KEAS) MACH	FUEL R/C Q	THETA GAMMA ALPHA	FLAP GAMDOT N	CMU CL/CLM A	CL CD CLMAX	FG FGP FGL	FR FRP FRL	NE NE NEL	TAU TAU TAUL	TEMP PRESS CS	BANK DIRECT SIDE	
47.49	153.69	0.0	21.756	0.0	0.4318	1.0122	53546.	14026.	2.0000	1.0000	534.22	0.0	20258.
8224.8	149.57	52.29	11.628	0.0281	0.5061	0.0801	0.	0.	2.0000	1.0000	2064.17	0.0	0.0
687.8	0.2289	75.74	10.128	0.9834	-0.0091	2.0000	0.	0.	0.0	0.0	671.32	0.0	
48.49	153.69	0.0	21.735	0.0	0.4325	1.0095	53553.	14015.	2.0000	1.0000	534.03	0.0	20306.
8478.9	149.45	52.35	11.642	-0.0001	0.5047	0.0799	0.	0.	2.0000	1.0000	2060.23	0.0	0.0
740.1	0.2290	75.61	10.093	0.9794	0.0044	2.0000	0.	0.	0.0	0.0	671.20	0.0	
48.68	153.69	0.0	21.750	0.0	0.4327	1.0102	53554.	14013.	2.0000	1.0000	534.00	0.0	20315.
8526.9	149.43	52.35	11.643	0.0032	0.5051	0.0799	0.	0.	2.0000	1.0000	2059.49	0.0	0.0
750.0	0.2290	75.59	10.107	0.9799	-0.0001	2.0000	0.	0.	0.0	0.0	671.18	0.0	
48.68	153.69	0.0	21.750	0.0	0.4327	1.0102	53554.	14013.	2.0000	1.0000	534.00	0.0	20315.
8526.9	149.43	52.35	11.643	0.0030	0.5051	0.0799	0.	0.	2.0000	1.0000	2059.49	0.0	0.0
750.0	0.2290	75.59	10.107	0.9798	-0.0001	2.0000	0.	0.	0.0	0.0	671.18	0.0	
49.18	153.58	0.0	19.250	0.0	0.3686	0.8103	45519.	12904.	2.0000	0.8500	533.90	0.0	16773.
8654.0	149.25	50.70	11.281	-1.4509	0.4052	0.0633	0.	0.	2.0000	0.8500	2057.50	0.0	0.0
775.8	0.2288	75.42	7.969	0.7766	-0.7889	2.0000	0.	0.	0.0	0.0	671.12	0.0	
49.68	153.24	0.0	16.750	0.0	0.3050	0.6684	37477.	11678.	2.0000	0.7000	533.81	0.0	13279.
8781.1	148.88	46.20	10.288	-2.5178	0.3342	0.0533	0.	0.	2.0000	0.7000	2055.69	0.0	0.0
800.0	0.2284	75.04	6.461	0.6306	-1.4423	2.0000	0.	0.	0.0	0.0	671.07	0.0	
49.81	153.13	0.0	16.083	0.0	0.2880	0.6386	35332.	11329.	2.0000	0.6600	533.80	0.0	12357.
8815.1	148.75	44.60	9.937	-2.7487	0.3193	0.0514	0.	0.	2.0000	0.6600	2055.29	0.0	0.0
806.0	0.2282	74.91	6.146	0.5996	-1.5874	2.0000	0.	0.	0.0	0.0	671.05	0.0	
49.81	153.13	0.0	16.083	0.0	0.2880	0.6386	35332.	11329.	2.0000	0.6600	533.80	0.0	12357.
8815.1	148.75	44.60	9.937	-2.7490	0.3193	0.0514	0.	0.	2.0000	0.6600	2055.30	0.0	0.0
806.0	0.2282	74.91	6.146	0.5996	-1.5876	2.0000	0.	0.	0.0	0.0	671.05	0.0	
50.31	152.81	0.0	13.583	0.0	0.2694	0.5477	35324.	11301.	2.0000	0.6600	533.72	1.500	12377.
8942.5	148.40	37.67	8.400	-3.4015	0.2739	0.0460	0.	0.	2.0000	0.6600	2053.71	0.024	0.0
826.6	0.2277	74.56	5.186	0.5135	-0.5539	2.0000	0.	0.	0.0	0.0	671.01	0.0	
50.81	152.73	0.0	13.616	0.0	0.2898	0.6910	35322.	11291.	2.0000	0.6600	533.66	3.000	12389.
9070.3	148.28	31.08	6.924	-2.4993	0.3455	0.0548	0.	0.	2.0000	0.6600	2052.48	0.109	0.0
843.8	0.2276	74.44	6.701	0.6441	-0.0039	2.0000	0.	0.	0.0	0.0	670.97	0.2	
51.31	152.72	0.0	14.980	0.0	0.2899	0.9049	35322.	11288.	2.0000	0.6600	533.61	4.500	12397.
9198.3	148.25	27.03	6.018	-1.1246	0.4525	0.0708	0.	0.	2.0000	0.6600	2051.40	0.288	0.0
853.3	0.2276	74.40	3.981	0.8398	-0.0040	2.0000	0.	0.	0.0	0.0	670.94	0.6	
51.81	152.72	0.0	15.472	0.0	0.2901	0.9917	35323.	11286.	2.0000	0.6600	533.56	6.000	12404.
9326.5	148.22	25.12	5.592	-0.5815	0.4958	0.0782	0.	0.	2.0000	0.6600	2050.43	0.579	0.0
871.4	0.2276	74.37	9.911	0.9190	-0.0046	2.0000	0.	0.	0.0	0.0	670.91	1.6	
52.31	152.72	0.0	15.686	0.0	0.2902	1.0349	35324.	11284.	2.0000	0.6600	533.52	7.500	12411.
9454.8	148.19	24.10	5.365	-0.3263	0.5174	0.0822	0.	0.	2.0000	0.6600	2049.51	0.977	0.0
883.7	0.2276	74.35	10.367	0.9562	-0.0036	2.0000	0.	0.	0.0	0.0	670.88	3.3	

FIGURE A-4.

A.2 Aerodynamic Characteristics

A.2.1 High Lift Configuration Aerodynamic Characteristics -

A.2.1.1 Externally-Blown-Flap - The high lift characteristics used for the E-150-3000 final design aircraft and the EBF oversized engines trade study (Section 3.3) are described in detail in Appendix B.2 of the NASA STOL Short-Haul System Study (Reference 1). This report presents wind tunnel based data for all engines operating and critical engine failed conditions for a range of flap angles, angles of attack and thrust levels. The use of direct lift control (DLC) and ground effects are also described.

A.2.1.2 Mechanical-Flap - STOL mechanical-flap high-lift systems are required to provide good increments in lift at a fixed angle of attack, high lift to drag ratios especially at takeoff and climb-out flap settings, and high values of maximum lift coefficient. In order to achieve these requirements a track-mounted flap with considerable aft extension with flap deflection is required. The following is a basic description of the selected high-lift system:

(1) The trailing edge flaps are track-mounted, 2-segment, double-slotted flaps employing considerable aft extension with flap deflection.

(2) The nested flap chord is 35 percent of the wing chord.

(3) The trailing edge flap is continuous spanwise from the fuselage to the aileron.

(4) A 15 percent chord full span leading edge slat is provided to prevent flow separation at high angles of attack.

The low-speed aerodynamic characteristics used for both the 3000-foot (914 m) and 4000-foot (1219 m) field length aircraft are based on advanced DC-9 high-lift systems similar to that described above. No corrections were necessary for sweep and aspect ratio since the base advanced DC-9 and the mechanical-flap STOL aircraft have similar wing planforms. The effects of Reynolds number on maximum lift coefficient were based on comparisons of wind tunnel test data and flight test data for the basic DC-9 configurations and were included in the estimated STOL mechanical flap aerodynamics.

The estimated out-of-ground effect longitudinally trimmed lift-and-drag characteristics for the 3000-foot (914 m) and the 4000-foot (1219 m) field length mechanical-flap high-lift configurations are presented in Figure A-5 . The maximum lift coefficients presented in Figure A-5 are 1 g values. Table A-1 presents maximum lift coefficients that were used under the V_{min} ground rules. Lateral-directional aerodynamic engine-out trim increments are not included in Figure A-5 since the thrust effects are handled separately in the performance analysis. The estimated engine-out lateral-directional trim increments used in the performance analysis are tabulated in Table A-2 .

The influence of ground effect on the aerodynamic characteristics were calculated from Douglas-derived empirical equations previously presented in NASA CR-114607 (Reference 1) in Appendix B.

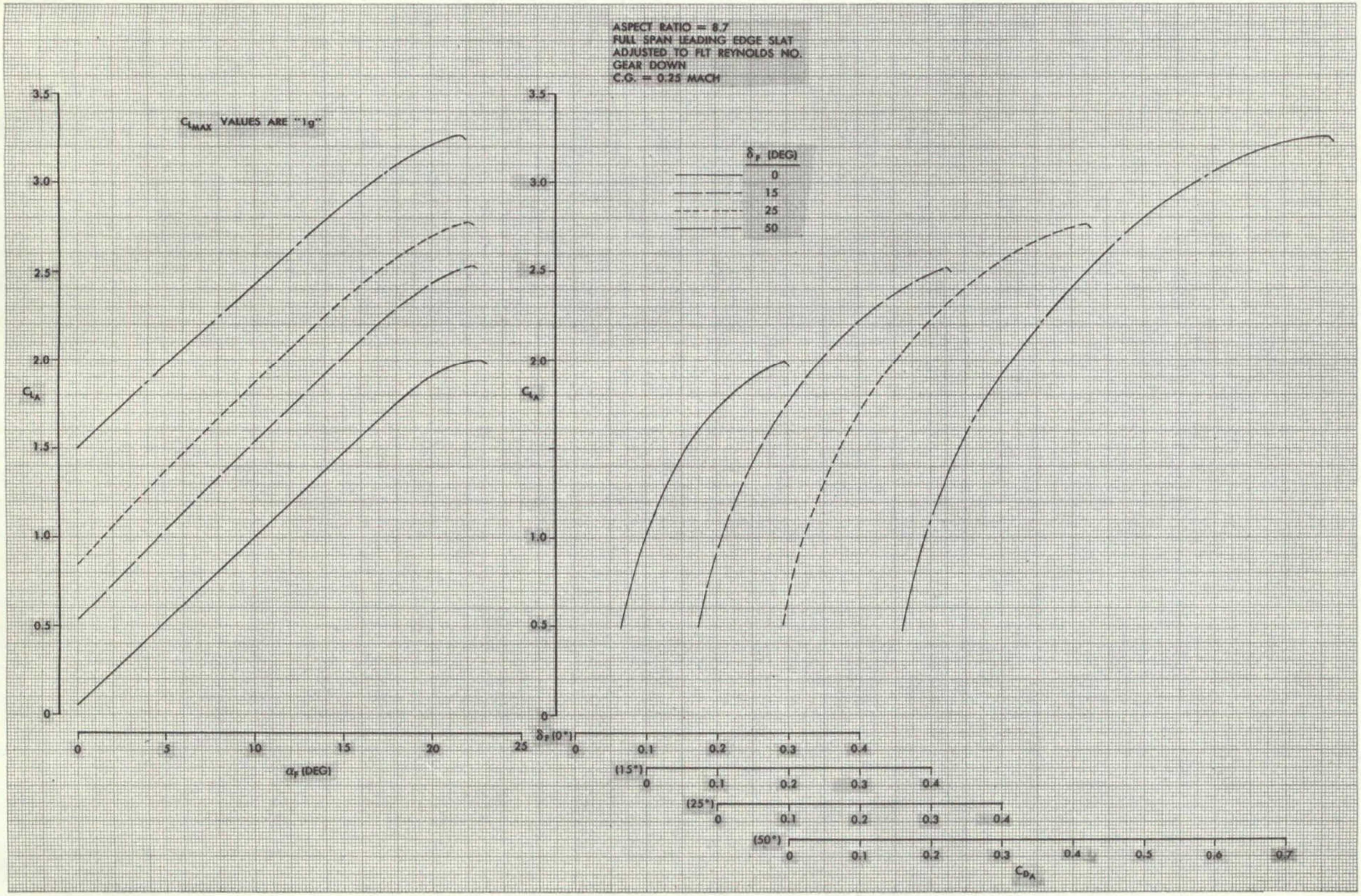


FIGURE A-5. TRIMMED LIFT AND DRAG CHARACTERISTICS FOR MECHANICAL FLAP AIRCRAFT

TABLE A-1

MECHANICAL-FLAP MAXIMUM LIFT COEFFICIENT

BASED ON V_{MIN} GROUND RULES

Slats Extended

δ_F (deg)	$C_{L_{max V_{min}}}$
0	2.06
15	2.68
25	2.89
50	3.39

TABLE A-2

TAKEOFF MECHANICAL-FLAP ENGINE-OUT LATERAL-DIRECTIONAL

TRIM INCREMENTS IN DRAG COEFFICIENT

FIELD LENGTH (ft)	$\Delta C_{D_{TRIM}}$
3000	.020
4000	.015

A.2.2 <u>High Speed Aerodynamic Characteristics</u> - The cruise drag characteristics for the final configurations have been estimated by the well-established Douglas drag prediction procedure for jet transport aircraft. The cruise drag consists of the zero-lift parasite drag and the drag due to lift at Mach numbers below those at which compressibility effects exist, plus the drag due to compressibility. The zero-lift parasite drag and the drag due to lift are evaluated at 0.5 Mach number, but at the Reynolds number corresponding to the design cruise points; in this way, the compressibility drag, which accounts for any drag increase at Mach numbers above 0.5, does not include a Reynolds number variation with Mach number. This procedure is identical to that used in the STOL System Study (Reference 1).

A breakdown of the estimated zero-lift parasite drag and a tabulation of the induced drag efficiency factors for the final M-150-3000 and M-150-4000 configurations are shown in Table A-3 . The total estimated trimmed cruise configuration drag characteristics (zero-lift parasite, lift dependent and compressibility drag) for these aircraft are shown in Figure A-6 for a range of lift coefficients and Mach numbers. Similar data for the final design E-150-3000 aircraft may be found in Appendix A of Reference 1.

TABLE A-3

LOW SPEED DRAG BREAKDOWN - FINAL MECHANICAL FLAP AIRCRAFT

Field Length ft (m)	3000	(914)	4000	(1219
Passengers	150		150	
Wing Area ft^2 (m^2)	2848	(264.6)	1679	(156.0)
EQUIVALENT PARASITE DRAG AREA, D/q_o ft^2 (m^2)				
Fuselage				
Friction, Form, Roughness*	9.3	(0.86)	9.2	(0.85)
Canopy	0.1	(0.01)	0.1	(0.01)
Aft Fuselage Upsweep	0.7	(0.07)	0.7	(0.07)
Gear Pods	2.9	(0.27)	2.5	(0.23)
Wing				
Friction, Form, Roughness	17.1	(1.59)	9.9	(0.92)
Flap Hinge Fairings	0.8	(0.07)	0.5	(0.05)
Horizontal Tail				
Friction, Form, Roughness	3.8	(0.35)	2.0	(0.19)
Elevator Hinge Fairings	0.2	(0.02)	0.1	(0.01)
Vertical Tail				
Friction, Form, Roughness	3.0	(0.28)	1.6	(0.15)
Nacelles and Pylons (Unscrubbed)				
Friction, Form, Roughness	3.0	(0.28)	2.6	(0.24)
Subtotal	40.9	(3.80)	29.2	(2.71)

TABLE A-3 (Continued)

LOW SPEED DRAG BREAKDOWN - FINAL MECHANICAL FLAP AIRCRAFT (cont'd)

EQUIVALENT PARASITE DRAG AREA, D/q_o ft^2 (m^2)				
Miscellaneous Items				
Excresences (7.1% of Subtotal)	2.9	(0.27)	2.1	(0.20)
Air Conditioning (0.7% of Subtotal)	0.3	(0.03)	0.2	(0.02)
Control Surface Gaps	0.7	(0.07)	0.6	(0.06)
Nacelle Interference @ $M \leq 0.6$	1.1	(0.10)	1.1	(0.10)
Contingency (5% of non N&P Items)	2.1	(0.20)	1.5	(0.14)
Total	48.0	(4.46)	34.7	(3.22)
C_{D_o}	0.0169		0.0207	
Induced Drag Efficiency Factor	0.768		0.767	

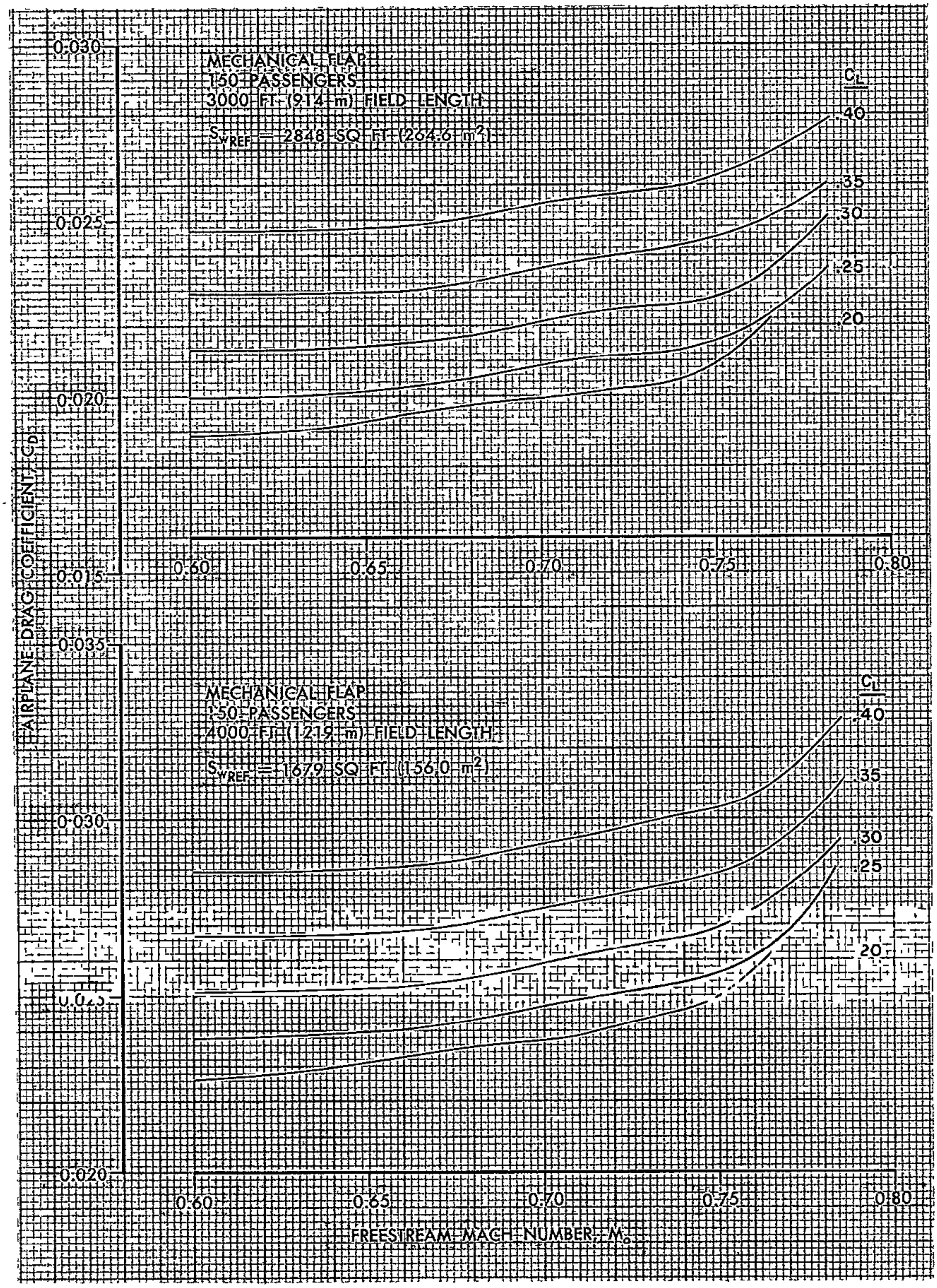


FIGURE A-6. ESTIMATED CRUISE CONFIGURATION DRAG CHARACTERISTICS

Appendix A.3 Mass Properties Data

This Appendix documents the mass properties efforts associated with defining baseline STOL aircraft for community noise impact studies. The methods used to derive these baseline weights are identical to those used in the NASA Short-Haul Systems Study, Reference 1. Therefore the weight substantiation and moment of inertia nomographs given in Appendix E, Volume II of that study report are representative of the aircraft presented herein.

The mass properties studies were completed in three phases. Section A.3.1 presents the results from task I which include weight summaries for two-versus four-engine mechanical-flap (MF) aircraft, and the installed engine weight variations as a function of fan pressure ratio (FPR) for treated and untreated nacelles.

Section A.3.2 includes the task II vehicle weight summaries from the propulsion/acoustics trade study, plus the weight results from the wing sensitivity study. Section A.3.3 presents the results from task III which include weight summaries for the externally-blown-flap (EBF) configuration with five- and ten-percent oversized engines, and the group weight breakdowns for the final design vehicles.

Because of the interrelationship between DOC and weight for the point design trade study aircraft, particular emphasis was placed on detailed weight analysis of the aircraft differences which are summarized in Figure A-7. Results show that variations in weight and DOC among the aircraft are small. Some examples of the details considered in the 400 component weight breakdown are:

FIGURE A-7

<u>DOC SENSITIVITY INVOLVES WEIGHT SENSITIVITY</u>

- NUMBER AND LOCATION OF ENGINES
- ENGINE COWL AND THRUST REVERSER CONFIGURATION
- PYLON LOCATION WITH RESPECT TO THE WING
- AIRCRAFT SPEED AND AERO DATA - GUST AND MANEUVER LOADS
- WING BOX GEOMETRY
- WING TO FUSELAGE CARRY-THROUGH
- CONTROL SURFACE CONFIGURATION

CLOSE ATTENTION TO DETAIL PREVENTS OVERLOOKED COMPONENT WEIGHTS.

2- Vs 4-Engine Mechanical-Flap Study

- Propulsion unit weights vary due to relative location of pylon to wing.
- Wing bending load relief and pylon attach bulkheads cause wing box weight variations.
- Engine instrument weights vary.
- Pneumatic system weights vary due to relative duct size and lengths.

Engine FPR Study

- Each section of cowling is weighed to account for differences in nacelle geometry (10 component breakdown).
- Thrust reverser and pylon geometry details are evaluated for weight impact for each engine configuration.
- Gust and maneuver load analyses are conducted for each point design to account for differences in aircraft speed, geometry and wing loading.

Wing Sensitivity Study

- A multi-station load/weight analysis of the wing box was conducted
- Wing to fuselage reaction loads were examined with respect to wing to fuselage carry through structure.

A.3.1 Task I Study Results. - Weight evaluations were made for a two- and a four-engine version of the 150-passenger, 3000-ft. (914.4m) field length mechanical-flap aircraft. The objective of this portion of the study was to select the best mechanical-flap configuration on which to perform engine and acoustic trade studies.

Weights are derived by a multi-step process as shown in Figure A-8, and the results are given in Table A-4. The gross weight for the four-engine version is slightly lower than for the two-engine configuration, but the latter was chosen for further study due to its lower direct operating cost.

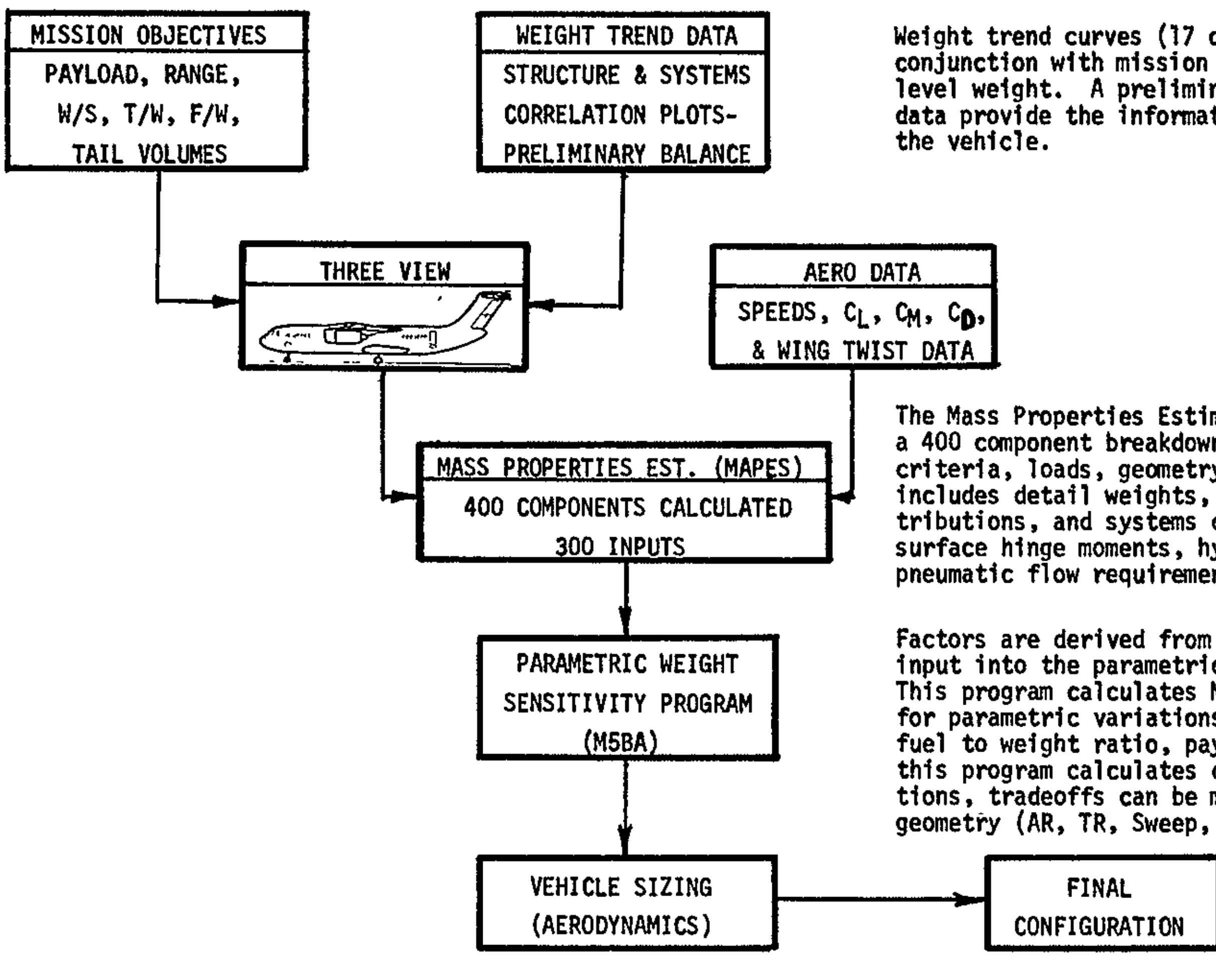
A multi-component weight analysis was made for the 1.32, 1.45, and 1.57 FPR engine installations. Geometry data required for the weight calculations are based on engine installation drawings. Both untreated and wall treated configurations were analyzed and the weight results tabulated in Table A-5. Since the geometry of the treated and untreated cases for a given FPR is identical, there is very little weight penalty assessed for treatment. The weight of the thrust reversers on the 1.45 and 1.57 FPR engines more than offsets the weight decrease due to reduction in wetted area with reduction in bypass ratio (BPR).

The nose cowl includes the inlet lip plus the inner and outer structure to the fan front face. The weight decreases with BPR due to decreasing inlet diameter and length. The fan cowl consists of the outer nacelle structure over the fan case. Again weight decreases with BPR due to fan diameter and case length.

The aft outer fan cowl extends from the fan cowl to the variable nozzle. This structure is included with the fan thrust reverser for the 1.45 and 1.57 FPR configurations. The fan exhaust duct and bifurcation includes the necessary structure for ducting the fan air exhaust from the rear fan face to the tip of the outer fan nozzle, except that in the areas of the fan thrust reverser and/or variable exhaust nozzle, the structure was included with those weights.

FIGURE A-8

VEHICLE SIZING



Weight trend curves (17 component breakdown) are used in conjunction with mission objective inputs to define a first level weight. A preliminary balance check is also made. These data provide the information needed to develop a three-view of the vehicle.

The Mass Properties Estimation System (MAPES) is used to develop a 400 component breakdown based on 300 inputs consisting of criteria, loads, geometry and system descriptions. Output includes detail weights, structural criteria, loads, load distributions, and systems design data (i.e., nacelle configuration, surface hinge moments, hydraulic flow rates, electrical output, pneumatic flow requirements).

Factors are derived from the 400 component weight breakdown for input into the parametric weight sensitivity program (M5BA). This program calculates MIL-STD-1374 functional weight breakdowns for parametric variations including thrust loading, wing loading, fuel to weight ratio, payload capacity and gross weight. Since this program calculates detail wing weights and load distributions, tradeoffs can be made with respect to weight versus wing geometry (AR, TR, Sweep, t/c, etc.).

TABLE A-4

DESIGN DATA AND WEIGHT SUMMARY - 2- VS 4-ENGINE STUDY

	TWO ENGINE		FOUR ENGINE	
HIGH LIFT CONCEPT	MECHANICAL FLAP		MECHANICAL FLAP	
NUMBER OF PASSENGERS	150		150	
FIELD LENGTH-FT(m)	3000	914.4	3000	914.4
TOGW-LB (kg)	173,550	78,721	172,900	78,426
WING AREA-FT^2(m^2)	2,878	267.4	2,867	266.4
ENGINE DESIGNATION	PD287-6	PD287-6	PD287-6	PD287-6
ENGINE THRUST-LB (N)	33,060	147,058	15,130	67,302
HORIZ/VERT TAIL AREA-FT^2(m^2)	649/574	60.3/53.3	642/561	59.6/52.1
HORIZ/VERT TAIL LENGTH-IN (cm)	800/600	2032/1524	800/610	2032/1549
HORIZ/VERT TAIL VOLUME	.754/.063	.754/.063	.750/.063	.750/.063
WING LOADING-LB/FT^2 (kg/m^2)	60.3	294	60.3	294
THRUST/TOGW	.381		.350	
FUEL WEIGHT/TOGW	.105	.105	.103	.103
FUSELAGE DIA/LENGTH-IN (cm)	180/1525	457/3874	180/1525	457/3874
WEIGHTS-LB (kg)				
WING	32,322	14,661	31,893	14,466
HORIZONTAL TAIL	3,218	1,460	3,183	1,444
VERTICAL TAIL	3,644	1,653	3,559	1,614
FUSELAGE	26,680	12,102	26,602	12,066
LANDING GEAR	7,289	3,306	7,262	3,294
FLIGHT CONTROLS	6,195	2,810	6,183	2,805
PROPULSION	16,527	7,496	16,650	7,552
FUEL SYSTEM	1,094	496	1,092	495
AUXILIARY POWER UNIT	950	431	950	431
INSTRUMENTS	1,175	533	1,245	565
HYDRAULICS	2,209	1,002	2,205	1,000
PNEUMATICS	775	351	1,110	503
ELECTRICAL	2,540	1,152	2,540	1,152
AVIONICS	1,760	798	1,760	798
FURNISHINGS	13,690	6,210	13,690	6,210
AIR CONDITIONING	1,430	649	1,430	649
ICE PROTECTION	752	341	746	338
HANDLING GEAR	30	14	30	14
MANUFACTURER'S EMPTY WEIGHT	122,280	55,465	122,130	55,396
OPERATIONAL ITEMS	2,980	1,352	2,980	1,352
OPERATIONAL EMPTY WEIGHT	125,260	56,817	125,110	56,749
PAYLOAD @ 200 LB/PAX (90.7 kg/pax)	30,000	13,608	30,000	13,608
FUEL-JP-4 @ 6.7 LB/GAL(802.9 kg/m^3)	18,290	8,296	17,790	8,069
TOGW	173,550	78,721	172,900	78,426

TABLE A-5

ENGINE INSTALLATION WEIGHTS

BYPASS RATIO FAN PRESSURE RATIO	12.8 1.32		9.2 1.45		5.9 1.57	
	ENGLISH	METRIC	ENGLISH	METRIC	ENGLISH	METRIC
THRUST-LB (N)	35,000	155,700	35,000	155,700	35,000	155,700
FAN DIAMETER-IN (cm)	93.6	238	87.0	221	81.2	206
BARE ENGINE LENGTH-IN (cm)	132.0	335	128.0	325	109.0	277
MAXIMUM NACELLE DIAMETER-IN (cm)	117.5	298	112.0	284	103.0	262
MAXIMUM NACELLE LENGTH-IN (cm)	244.7	622	266.1	676	230.0	584
ENGINE THRUST/WEIGHT-UNINSTALLED	6.692		6.737		6.913	
ENGINE THRUST/WEIGHT-INSTALLED UNTREATED	4.255		3.716		4.000	
ENGINE THRUST/WEIGHT-INSTALLED TREATED	4.240		3.713		3.998	
WEIGHTS-LB (kg)						
NOSE COWL	538	244	459	208	426	193
FAN COWL	242	110	212	96	169	77
AFT OUTER FAN COWL	100	45	0	0	0	0
FAN EXHAUST DUCT AND BIFURCATION	239	108	242	110	194	88
VARIABLE EXHAUST NOZZLE	289	131	244	111	0	0
FAN THRUST REVERSER	0	0	1,089	494	1,046	474
PRIMARY THRUST REVERSER	0	0	595	270	549	249
CORE COWL	225	102	52	23	47	21
TAIL PIPE	125	57	0	0	0	0
TAIL CONE	23	11	61	28	49	22
ENGINE SYSTEMS	315	143	315	143	315	143
SUBTOTAL	2,096	951	3,269	1,483	2,795	1,267
DRY ENGINE	5,230	2,372	5,195	2,356	5,063	2,297
SUBTOTAL	7,326	3,323	8,464	3,839	7,858	3,564
PYLON	900	408	955	433	893	405
TOTAL UNTREATED WEIGHT	8,226	3,731	9,419	4,272	8,751	3,969
TREATMENT PENALTY-NOSE COWL	19	9	8	4	4	2
TREATMENT PENALTY-FAN DUCT	9	4	0	0	0	0
TOTAL ACOUSTIC TREATED WEIGHT	8,254	3,744	9,427	4,276	8,755	3,971

The variable exhaust nozzle forms the tip of the outer fan exhaust duct and is not required for the 1.57 FPR engine. The thrust reversers are cascade types and are not required for the 1.32 FPR variable-pitch engine.

The core cowl extends from the end of the fan exhaust duct to the end of the tailpipe. Part of its weight was included with the primary thrust reverser for the 1.45 and 1.57 FPR configurations. The tailpipe weight is also part of the primary thrust reverser for the 1.45 and 1.57 FPR installations. The tailcone is shorter for the 1.32 FPR engine since the primary exhaust duct length was decreased due to no thrust reverser requirement.

The pylon unit weight (based on pylon side profile area) was based on the weight of the demountable power plant, its location relative to the wing and the side profile area of the pylon. The unit weight variations were small and very close to the minimum unit weight due to only a slight cantilever of the engine with respect to the wing. Therefore, pylon weight was almost purely a function of pylon area which varies directly with nacelle length.

A.3.2 Task II Study Results. - Weights were derived for the mechanical-flap 3000-ft. (914.4m) and 4000-ft. (1219m) field length aircraft with each of the three candidate engine installations studied in task I. Each of the vehicles were sized in accordance with the process described in Figure A-8. The objective was to select the acoustic trade study configuration which would be evaluated for community noise impact along with the EBF airplane. Both untreated and wall treated engine installation weights are tabulated in Table A-6, but the latter was selected based on lower noise for less than 0.3 percent increase in takeoff gross weight. The 1.57 FPR engine was selected for both 3000-ft. (914.4m) and 4000-ft. (1219m) field length since

TABLE A-6

150 PASSENGER 3000' FIELD LENGTH MECHANICAL FLAP AIRCRAFT FOR ACOUSTIC TRADE STUDY

	NO ACOUSTIC TREATMENT						WALL TREATMENT					
ENGINE FAN PRESSURE RATIO	1.32		1.45		1.57		1.32		1.45		1.57	
	ENGLISH	METRIC	ENGLISH	METRIC	ENGLISH	METRIC	ENGLISH	METRIC	ENGLISH	METRIC	ENGLISH	METRIC
GEOMETRY DATA												
WING AREA $FT^2 (m^2)$	2,775	257.8	2,858	265.5	2,844	264.2	2,782	258.4	2,863	266.0	2,848	264.6
WING LOADING $LB/FT^2 (kg/m^2)$	60.5	295.4	60.5	295.4	60.5	295.4	60.5	295.4	60.5	295.4	60.5	295.4
HORIZONTAL TAIL AREA $FT^2 (m^2)$	642	59.6	660	61.3	654	60.7	643	59.8	661	61.4	654	60.8
HORIZONTAL TAIL VOLUME	.787	.787	.775	.775	.773	.773	.786	.786	.774	.774	.772	.772
VERTICAL TAIL AREA $FT^2 (m^2)$	543	50.5	568	52.8	564	52.4	545	50.7	569	52.9	565	52.5
VERTICAL TAIL VOLUME	.063	.063	.063	.063	.063	.063	.063	.063	.063	.063	.063	.063
SLS THRUST/TOGW	.370	-	.362	-	.355	-	.371	-	.364	-	.356	-
SLS THRUST PER ENGINE LB (N)	31,050	138,117	31,330	139,363	30,570	135,982	31,240	138,962	31,490	140,074	30,680	136,471
FUEL WEIGHT/TOGW	.103	.103	.105	.105	.112	.112	.103	.103	.105	.105	.112	.112
CRUISE MACH NUMBER	.66	.66	.68	.68	.74	.74	.66	.66	.68	.68	.74	.74
WEIGHT DATA LB(kg)												
WING	30,631	13,894	31,562	14,316	31,392	14,239	30,714	13,932	31,628	14,346	31,441	14,261
TAIL	6,627	3,006	6,876	3,119	6,817	3,092	6,649	3,016	6,890	3,125	6,827	3,097
FUSELAGE	26,395	11,972	26,587	12,060	26,556	12,046	26,410	11,979	26,599	12,065	26,563	12,049
LANDING GEAR	7,052	3,199	7,263	3,294	7,228	3,278	7,069	3,207	7,275	3,300	7,236	3,282
PROPULSION	15,669	7,107	17,953	8,143	16,374	7,427	15,810	7,171	18,054	8,189	16,437	7,456
REMAINING WEIGHT	31,244	14,172	31,490	14,284	31,445	14,263	31,266	14,182	31,505	14,291	31,458	14,269
MANUFACTURER EMPTY WEIGHT	117,618	53,350	121,731	55,216	119,812	54,345	117,918	53,487	121,951	55,316	119,962	54,414
OPERATIONAL ITEMS	2,972	1,348	2,979	1,351	2,978	1,351	2,972	1,348	2,979	1,351	2,978	1,351
OPERATIONAL EMPTY WEIGHT	120,590	54,698	124,710	56,567	122,790	55,696	120,890	54,835	124,930	56,667	122,940	55,765
PAYLOAD @ 200 LB/PAX (90.7 kg/pax)	30,000	13,608	30,000	13,608	30,000	13,608	30,000	13,608	30,000	13,608	30,000	13,608
ZERO FUEL WEIGHT	150,590	68,306	154,710	70,175	152,790	69,304	150,890	68,443	154,930	70,275	152,940	69,373
FUEL JP-4 @ 6.7 LB/GAL $(802.9\ kg/m^3)$	17,310	7,852	18,190	8,251	19,310	8,759	17,410	7,897	18,270	8,287	19,360	8,781
TAKEOFF GROSS WEIGHT	167,900	76,158	172,900	78,426	172,100	78,063	168,300	76,340	173,200	78,562	172,300	78,154

TABLE A-6 (CONT)
150 PASSENGER 4000' FIELD LENGTH MECHANICAL FLAP AIRCRAFT FOR ACOUSTIC TRADE STUDY

	NO ACOUSTIC TREATMENT						WALL TREATMENT					
ENGINE FAN PRESSURE RATIO	1.32		1.45		1.57		1.32		1.45		1.57	
	ENGLISH	METRIC	ENGLISH	METRIC	ENGLISH	METRIC	ENGLISH	METRIC	ENGLISH	METRIC	ENGLISH	METRIC
GEOMETRY DATA												
WING AREA $FT^2(m^2)$	1,641	152.4	1,684	156.4	1,678	155.9	1,644	152.7	1,687	156.7	1,679	156.0
WING LOADING $LB/FT^2(kg/m^2)$	85.5	417.4	85.5	417.4	85.5	417.4	85.5	417.4	85.5	417.4	85.5	417.4
HORIZONTAL TAIL AREA $FT^2(m^2)$	334	31.0	342	31.7	339	31.5	334	31.0	343	31.8	339	31.5
HORIZONTAL TAIL VOLUME	.830	.830	.818	.818	.815	.815	.829	.829	.818	.818	.814	.814
VERTICAL TAIL AREA $FT^2(m^2)$	306	28.4	318	29.5	316	29.4	307	28.5	319	29.6	317	29.4
VERTICAL TAIL VOLUME	.078	.078	.078	.078	.078	.078	.078	.078	.078	.078	.078	.078
SLS THRUST/TOGW	.392	-	.383	-	.373	-	.393	-	.384	-	.374	-
SLS THRUST PER ENGINE LB (N)	27,490	122,282	27,540	122,504	26,780	119,123	27,660	123,038	27,670	123,082	26,870	119,524
FUEL WEIGHT/TOGW	.100	.100	.104	.104	.112	.112	.101	.101	.104	.104	.112	.112
CRUISE MACH NUMBER	.69	.69	.71	.71	.77	.77	.69	.69	.71	.71	.77	.77
WEIGHT DATA LB(kg)												
WING	18,506	8,394	19,022	8,628	18,941	8,591	18,542	8,410	19,057	8,644	18,954	8,597
TAIL	3,398	1,541	3,509	1,592	3,485	1,581	3,406	1,545	3,519	1,596	3,492	1,584
FUSELAGE	23,793	10,792	23,831	10,810	23,826	10,807	23,796	10,794	23,833	10,811	23,827	10,808
LANDING GEAR	5,893	2,673	6,048	2,743	6,025	2,733	5,905	2,678	6,057	2,747	6,031	2,736
PROPULSION	13,748	6,236	15,660	7,103	14,227	6,453	13,873	6,293	15,743	7,141	14,278	6,476
REMAINING WEIGHT	28,000	12,701	28,124	12,757	28,100	12,746	28,016	12,708	28,132	12,761	28,103	12,747
MANUFACTURER EMPTY WEIGHT	93,338	42,337	96,194	43,633	94,604	42,911	93,538	42,428	96,341	43,700	94,685	42,948
OPERATIONAL ITEMS	2,862	1,298	2,866	1,300	2,866	1,300	2,862	1,298	2,867	1,300	2,866	1,300
OPERATIONAL EMPTY WEIGHT	96,200	43,635	99,060	44,933	97,470	44,211	96,400	43,726	99,208	45,000	97,551	44,248
PAYLOAD @ 200 LB/PAX (90.7 kg/pax)	30,000	13,608	30,000	13,608	30,000	13,608	30,000	13,608	30,000	13,608	30,000	13,608
ZERO FUEL WEIGHT	126,200	57,243	129,060	58,541	127,470	57,819	126,400	57,334	129,208	58,608	127,551	57,856
FUEL JP-4 @ 6.7 LB/GAL (802.9 kg/m^3)	14,100	6,396	14,940	6,776	16,030	7,271	14,200	6,441	14,992	6,800	16,049	7,280
TAKEOFF GROSS WEIGHT	140,300	63,639	144,000	65,317	143,500	65,090	140,600	63,775	144,200	65,408	143,600	65,136

the direct operating costs are lower due to less expensive engines and higher block speeds.

The task II study includes the effects of thickness ratio and sweep on the EBF, 3000-ft. (914.4m) field length airplane. The results of the weight sensitivity portion of the study are given in Table A-7.

Delta weights were first determined for each of the structural components affected, as shown in the upper half of the table. The horizontal tail sweep and thickness ratio vary with the wing but the vertical tail geometry remains fixed. The delta weights are based on constant wing area, takeoff gross weight and tail volume.

The aircraft were then resized in accordance with the process described in Figure A-8. The resultant weights are given in the lower half of Table A-7.

A.3.3 Task III Study Results. - The task III study required evaluation of aircraft operational techniques on community noise. One way to achieve a reduction in noise level is with oversized engines which provide greater climb capability. The increase in weight due to higher thrust can be partially offset by increased wing loading. Increases of five- and ten-percent in thrust were studied for the EBF baseline aircraft. The weight results of this study are shown in Table A-8.

Weight summaries for the four final design aircraft are given in Tables A-9, A-10, and A-11. The four aircraft consist of the four-engine EBF 3000-ft. (914.4m) field length aircraft with and without ten percent oversized engines, and the mechanical-flap 3000-ft. (914.4m) and 4000-ft. (1219m) field length vehicles each with two 1.57 FPR engines. The EBF final

TABLE A-7
EBF WING SENSITIVITY STUDY - WEIGHT SUMMARY

CONFIGURATION SWEEP (Degrees) t/c (mean)	BASELINE 25 .1375		DELTA WEIGHTS FROM E-150-3000; CONSTANT Sw, TOGW, TAIL VOLUME 1 25 .10		2 25 .16		3 15 .1375		4 5.6 .1375	
	ENGLISH	METRIC	ENGLISH	METRIC	ENGLISH	METRIC	ENGLISH	METRIC	ENGLISH	METRIC
COMPONENT WEIGHTS-LB(kg):										
WING SURFACE MATERIAL	5,807	2,634	+ 1,369	+ 621	- 450	- 204	- 543	- 246	- 752	- 341
WING SHEAR MATERIAL	1,025	465	0	0	0	0	- 57	- 26	- 80	- 36
WING RIBS AND BULKHEADS	1,378	625	+ 95	+ 43	- 4	- 2	+ 29	+ 13	+ 37	+ 17
FUSELAGE BULKHEADS AT WING ATTACH	312	141	- 4	- 2	+ 1	+ 1	- 130	- 59	- 216	- 98
WING FUSELAGE ATTACH FITTINGS	396	180	- 5	- 2	+ 2	+ 1	- 165	- 75	- 274	- 124
HORIZONTAL TAIL-WEIGHT	2,582	1,171								
BOX CHANGE (due to t/c and sweep changes)			+ 212	+ 96	- 74	- 34	- 91	- 41	- 128	- 58
CHANGE DUE TO TAIL LENGTH CHANGE			0		0		+ 65	+ 29	+ 133	+ 60
TOTALS	11,500	5,216	+ 1,667	+ 756	- 525	- 238	- 892	- 405	- 1,280	- 580

	EFFECTS DUE TO AIRCRAFT RESIZING									
CONFIGURATION DESCRIPTION:										
WING AREA-FT^2(m^2)	1,461	135.7	1,493	138.7	1,452	134.9	1,391	129.2	1,374	127.6
WING LOADING-LB/FT^2 (kg/m^2)	102	498	102	498	102	498	105	513	105	513
HORIZ/VERT TAIL AREA-FT^2 (m^2)	419/319	38.9/29.6	425/329	39.4/30.5	416/317	38.7/29.4	422/308	39.2/28.6	430/303	39.9/28.1
HORIZ/VERT TAIL LENGTH-IN (cm)	885/735	2248/1867	885/735	2248/1867	885/735	2248/1867	863/735	2192/1867	842/735	2139/1867
HORIZ/VERT TAIL VOLUME	1.426/.124	1.426/.124	1.400/.123	1.400/.123	1.431/.124	1.431/.124	1.511/.129	1.511/.129	1.528/.129	1.528/.129
THRUST PER ENGINE-LB (N)	18,260	81,225	18,660	83,004	18,140	80,691	17,600	78,289	16,950	75,397
THRUST LOADING-LB/LB	.490	-	.490	-	.490	-	.482	-	.470	-
FUEL WEIGHT/TOGW	.110	.110	.109	.109	.111	.111	.111	.111	.110	.110
MAXIMUM FUEL VOLUME (incl center wing)-LB(kg)	54,144	24,559	40,653	18,440	62,449	28,326	50,300	22,816	49,381	22,399
CRUISE MACH NUMBER	.69	.69	.70	.70	.69	.69	.68	.68	.67	.67
WEIGHTS-LB (kg):										
TAKEOFF GROSS WEIGHT	149,000	67,585	152,300	69,082	148,100	67,177	146,000	66,224	144,300	65,453
Δ TAKEOFF GROSS WEIGHT	0	0	+ 3,300	+ 1,497	- 940	- 426	- 2,980	- 1,352	- 4,740	- 2,150
Δ OPERATIONAL EMPTY WEIGHT	0	0	+ 3,100	+ 1,406	- 980	- 445	- 2,830	- 1,284	- 4,280	- 1,941

TABLE A-8
EBF WITH OVERSIZED ENGINES

		BASE AIRCRAFT		5% OVERSIZED		10% OVERSIZED	
		English	Metric	English	Metric	English	Metric
GEOMETRY DATA							
WING AREA	$FT^2 (m^2)$	1461	135.7	1430	132.8	1400	130.1
WING LOADING	$LB/FT^2 (kg/m^2)$	102	498	105	512.6	108	527.3
HORIZ/VERT TAIL AREA	$FT^2 (m^2)$	419/319	38.9/29/6	420/320	39.0/29.7	421/319	39.1/29.6
HORIZ/VERT TAIL VOLUME		1.426/.124	1.426/.124	1.477/.131	1.477/.131	1.528/.132	1.528/.132
SLS THRUST/TOGW		.490	-	.510	-	.530	-
SLS THRUST PER ENGINE	LB (N)	18,260	81,225	19,160	85,228	20,040	89,142
FUEL WEIGHT/TOGW		.110	.110	.112	.112	.114	.114
WEIGHT DATA	LB (kg)						
WING		18,070	8,196	17,793	8,071	17,509	7,942
TAIL		4,625	2,098	4,637	2,103	4,640	2,105
FUSELAGE		23,405	10,616	23,422	10,624	23,440	10,632
LANDING GEAR		6,260	2,840	6,306	2,860	6,352	2,881
PROPULSION		19,470	8,832	20,380	9,244	21,272	9,649
REMAINING WEIGHT		27,940	12,673	27,915	12,662	27,853	12,634
MANUFACTURER EMPTY WEIGHT		99,770	45,255	100,453	45,564	101,066	45,843
OPERATIONAL ITEMS		2,840	1,288	2,837	1,287	2,834	1,285
OPERATIONAL EMPTY WEIGHT		102,610	46,543	103,290	46,851	103,900	47,128
PAYLOAD @ 200 LB/PAX (90.7 kg/pax)		30,000	13,608	30,000	13,608	30,000	13,608
ZERO FUEL WEIGHT		132,610	60,151	133,290	60,459	133,900	60,736
FUEL JP-4 @ 6.7 LB/GAL (802.9 kg/m^3)		16,390	7,434	16,810	7,625	17,300	7,847
TAKEOFF GROSS WEIGHT		149,000	67,585	150,100	68,084	151,200	68,583

TABLE A-9

WEIGHT SUMMARY

HIGH LIFT CONCEPT	EXTERNALLY BLOWN FLAP		EBF+10% OVERSIZED ENG		MECHANICAL FLAP			
NUMBER OF PASSENGERS	150		150		150			
FIELD LENGTH - FT (m)	3000	914.4	3000	914.4	3000	914.4	4000	1219
DESIGN CRUISE MACH NO.	.69	.69	.71	.71	.74	.74	.77	.77
MISSION RANGE - S-MILES (km)	575	926	575	926	575	926	575	926
ENGINE DESIGNATION (BPR/FAN PRESS RATIO)	PD287-3	PD287-3	PD287-3	PD287-3	5.9/1.57	5.9/1.57	5.9/1.57	5.9/1.57
NO. OF WING MTD ENG/AIRPL	4	4	4	4	2	2	2	2
DIMENSIONAL DATA								
WING AREA - FT^2 (m^2)	1,461	135.7	1,400	130.1	2,848	264.6	1,679	156.0
WING LOADING - LBS/FT^2 (kg/m^2)	102	498	108	527	60.5	295.4	85.5	417.4
HORIZONTAL TAIL AREA - FT^2 (m^2)	419	38.9	421	39.1	654	60.8	339	31.5
HORIZONTAL TAIL ARM - IN(cm)	885	2,248	885	2,248	800	2,032	738	1,875
HORIZONTAIL TAIL VOLUME	1.426	1.426	1.528	1.528	.772	.772	.814	.814
VERTICAL TAIL AREA - FT^2 (m^2)	319	29.6	319	29.6	565	52.5	317	29.4
VERTICAL TAIL ARM - IN(cm)	735.	1,867	735	1,867	600	1,524	600	1,524
VERTICAL TAIL VOLUME	.1238	.1238	.1320	.1320	.063	.063	.078	.078
MAXIMUM FUSELAGE LENGTH - IN(cm)	1,500	3,810	1,500	3,810	1,525	3,874	1,475	3,747
MAXIMUM FUSELAGE DEPTH - IN(cm)	180	457	180	457	180	457	180	457
MAXIMUM FUSELAGE WIDTH - IN(cm)	180	457	180	457	180	457	180	457
SLS THRUST (UNINST)/TOGW	.490	.490	.530	.530	.356	.356	.374	.374
SLS THRUST (UNINST)/ENG - LBS(N)	18,260	81,225	20,040	89,142	30,680	136,471	26,870	119,524
NO. OF ACOUSTIC RINGS (INLET/EXH)	0	0	0	0	0	0	0	0
MISSION FUEL WEIGHT/TOGW	.110	.110	.114	.114	.112	.112	.112	.112

TABLE A-9 (CONT)

WEIGHT SUMMARY

HIGH LIFT CONCEPT	EXTERNALLY BLOWN FLAP		EBF+10% OVERSIZED ENG		MECHANICAL FLAP			
NUMBER OF PASSENGERS	150		150		150			
FIELD LENGTH - FT (m)	3000	914.4	3000	914.4	3000	914.4	4000	1219
WEIGHTS	lb	kg	lb	kg	lb	kg	lb	kg
WING GROUP	18,070	8,196	17,509	7,942	31,441	14,261	18,954	8,597
TAIL GROUP	4,625	2,098	4,640	2,105	6,827	3,097	3,492	1,584
BODY GROUP	23,405	10,616	23,440	10,632	26,563	12,049	23,827	10,808
ALIGHTING GEAR GROUP	6,260	2,839	6,352	2,881	7,236	3,282	6,031	2,736
SURFACE CONTROLS GROUP	3,500	1,588	3,428	1,555	6,148	2,789	3,850	1,746
ENGINE SECTION OR NACELLE GROUP	7,090	3,216	7,778	3,528	2,873	1,303	2,516	1,141
PROPULSION GROUP	12,380	5,616	13,494	6,121	13,564	6,153	11,762	5,335
AUXILIARY POWER PLANT GROUP	950	431	950	431	950	431	950	431
INSTRUMENTS & NAVIGATIONAL EQUIP. GROUP	1,175	533	1,175	533	1,175	533	1,175	533
HYDRAULIC & PNEUMATIC GROUP	2,285	1,036	2,280	1,034	2,993	1,357	2,108	956
ELECTRICAL GROUP	2,590	1,175	2,590	1,175	2,540	1,152	2,540	1,152
ELECTRONICS GROUP	1,760	798	1,760	798	1,760	798	1,760	798
FURNISHINGS GROUP	13,690	6,210	13,690	6,210	13,690	6,210	13,690	6,210
AIRCONDITIONING & ANTI-ICING EQPT GROUP	1,960	889	1,950	884	2,172	985	2,000	907
AUXILIARY GEAR GROUP	30	14	30	14	30	14	30	14
MANUFACTURER EMPTY WEIGHT	99,770	45.255	101,066	45,843	119,962	54,414	94,685	42,948
OPERATIONAL ITEM WEIGHT	2,840	1,288	2,834	1,285	2,978	1,351	2,866	1,300
OPERATIONAL EMPTY WEIGHT	102,610	46,543	103,900	47,128	122,940	55,765	97,551	44,248
MISSION PAYLOAD WEIGHT *	30,000	13,608	30,000	13,608	30,000	13,608	30,000	13,608
MISSION ZERO FUEL WEIGHT	132,610	60,151	133,900	60,736	152,940	69,373	127,551	57,856
MISSION FUEL WEIGHT **	16,390	7,434	17,300	7,847	19,360	8,781	16,049	7,280
STOL TAKEOFF GROSS WEIGHT	149,000	67,585	151,200	68,583	172,300	78,154	143,600	65,136
COST WEIGHT	87,315	39,605	87,536	39,706	109,169	49,518	85,314	38,698
AMPR WEIGHT	84,235	38,208	84,456	38,309	106,139	48,144	82,284	37,324

* PAYLOAD @ 200 LBS/PAX (90.7 kg/PAX)   ** JP-4 @ 6.7 LB/GAL (802.9 kg/m3)

TABLE A-10

GROUP WEIGHT SUMMARY

HIGH LIFT CONCEPT	EXTERNALLY BLOWN FLAP		EBF+10% OVERSIZED ENG		MECHANICAL FLAP			
NUMBER OF PASSENGERS	150		150		150			
FIELD LENGTH - FT (m)	3000	914.4	3000	914.4	3000	914.4	4000	1219
UNITS	lb	kg	lb	kg	lb	kg	lb	kg
EMPTY WEIGHT SUMMARY:								
WING GROUP	(18,070)	(8,196)	(17,509)	(7,942)	(31,441)	(14,261)	(18,954)	(8,597)
BOX STRUCTURE	9,866	4,475	9,686	4,394	16,329	7,407	10,386	4,711
SECONDARY STRUCTURE	1,916	869	1,827	829	3,848	1,745	2,285	1,036
AILERONS	362	164	345	156	627	284	333	151
FLAPS - TRAILING EDGE	4,266	1,935	4,068	1,845	6,745	3,060	3,700	1,678
- LEADING EDGE	450	204	430	195	0	0	0	0
SLATS	681	309	649	294	2,802	1,271	1,653	750
SPOILERS	529	240	504	229	1,090	494	597	271
TAIL GROUP	(4,625)	(2,098)	(4,640)	(2,105)	(6,827)	(3,097)	(3,492)	(1,584)
STABILIZER - BASIC STRUCTURE	1,247	566	1,254	569	2,047	929	979	444
FINS - BASIC STRUCTURE	1,415	642	1,417	643	2,744	1,245	1,407	638
SECONDARY STRUCTURE (STAB. AND FINS)	298	135	300	136	466	211	242	110
ELEVATORS	655	297	658	299	729	331	369	167
RUDDER	628	285	629	285	841	381	495	225
SLATS - STABILIZER	382	173	382	173	0	0	0	0
BODY GROUP	(23,405)	(10,616)	(23,440)	(10,632)	(26,563)	(12,049)	(23,827)	(10,808)
FUSELAGE - BASIC STRUCTURE	17,060	7,738	17,095	7,754	19,524	8,856	17,092	7,753
SECONDARY STRUCTURE								
MAIN LANDING GEAR PODS	519	236	519	236	940	426	784	355
AIRSTAIRS	1,330	603	1,330	603	1,765	801	1,494	678
DOORS, PANELS & MISC	4,496	2,039	4,496	2,039	4,334	1,966	4,457	2,022

TABLE A-10 (CONT)
GROUP WEIGHT SUMMARY

HIGH LIFT CONCEPT	EXTERNALLY BLOWN FLAP		EBF+10% OVERSIZED ENG		MECHANICAL FLAP			
NUMBER OF PASSENGERS	150		150		150			
FIELD LENGTH - FT (m)	3000	914.4	3000	914.4	3000	914.4	4000	1219
UNITS	lb	kg	lb	kg	lb	kg	lb	kg
ALIGHTING GEAR GROUP	(6,260)	(2,839)	(6,352)	(2,881)	(7,236)	(3,282)	(6,031)	(2,736)
MAIN GEAR								
ROLLING ASSEMBLY	1,425	646	1,445	655	1,646	747	1,372	622
GEAR STRUCTURE	3,102	1,407	3,146	1,427	3,584	1,626	2,987	1,355
CONTROLS	453	205	459	208	523	237	436	198
TOTAL MAIN GEAR	4,980	2,258	5,050	2,290	5,753	2,610	4,795	2,175
NOSE GEAR								
ROLLING ASSEMBLY	235	107	237	108	270	122	225	102
GEAR STRUCTURE	789	358	805	365	917	416	764	347
CONTROLS	256	116	260	118	296	134	247	112
TOTAL NOSE GEAR	1,280	581	1,302	591	1,483	672	1,236	561
SURFACE CONTROLS GROUP	(3,500)	(1,588)	(3,428)	(1,555)	(6,148)	(2,789)	(3,850)	(1,746)
COCKPIT CONTROLS	85	39	85	39	85	39	85	39
AUTOMATIC PILOT	240	109	240	109	240	109	240	109
SYSTEM CONTROLS	3,175	1,440	3,103	1,407	5,823	2,641	3,525	1,598
ENGINE SECTION OR NACELLE GROUP	(7,090)	(3,216)	(7,778)	(3,528)	(2,873)	(1,303)	(2,516)	(1,141)
INBOARD	3,545	1,608	3,889	1,764	2,873	1,303	2,516	1,141
OUTBOARD	3,545	1,608	3,889	1,764	0	0	0	0

TABLE A-10 (CONT)
GROUP WEIGHT SUMMARY

HIGH LIFT CONCEPT	EXTERNALLY BLOWN FLAP		EBF+10% OVERSIZED ENG		MECHANICAL FLAP			
NUMBER OF PASSENGERS	150		150		150			
FIELD LENGTH - FT (m)	3000	914.4	3000	914.4	3000	914.4	4000	1219
UNITS	lb	kg	lb	kg	lb	kg	lg	kg
PROPULSION GROUP	(12,380)	(5,616)	(13,494)	(6,121)	(13,564)	(6,153)	(11,762)	(5,335)
ENGINE INSTALLATION	10,795	4,897	11,848	5,374	8,877	4,027	7,774	3,526
EXHAUST SYSTEM	360	163	395	179	426	193	374	170
COOLING SYSTEM	91	41	99	45	76	34	67	30
FUEL SYSTEM	779	353	763	346	1,088	494	835	379
ENGINE CONTROLS	65	30	71	32	51	23	44	20
STARTING SYSTEM	290	132	318	145	248	113	217	98
THRUST REVERSER	0	0	0	0	2,798	1,269	2,451	1,112
AUXILIARY POWER PLANT GROUP	(950)	(431)	(950)	(431)	(950)	(431)	(950)	(431)
INSTRUMENTS & NAVIGATIONAL EQUIP GROUP	(1,175)	(533)	(1,175)	(533)	(1,175)	(533)	(1,175)	(533)
HYDRAULIC & PNEUMATIC GROUP	(2,285)	(1,036)	(2,280)	(1,034)	(2,993)	(1,357)	(2,108)	(956)
HYDRAULIC SYSTEM	1,278	580	1,253	568	2,192	994	1,373	623
PNEUMATIC SYSTEM	1,007	456	1,027	466	801	363	735	333
ELECTRICAL GROUP	(2,590)	(1,175)	(2,590)	(1,175)	(2,540)	(1,152)	(2,540)	(1,152)
ELECTRONICS GROUP	(1,760)	(798)	(1,760)	(798)	(1,760)	(798)	(1,760)	(798)
EQUIPMENT	1,074	487	1,074	487	1,074	487	1,074	487
INSTALLATION	686	311	686	311	686	311	686	311
FURNIHSINGS GROUP	(13,690)	(6,210)	(13,690)	(6,210)	(13,690)	(6,210)	(13,690)	(6,210)
AIRCONDITIONING & ANTI-ICING EQUIP GRP	(1,960)	(889)	(1,950)	(884)	(2,172)	(985)	(2,000)	(907)
AIRCONDITIONING	1,430	649	1,430	649	1,430	649	1,430	649
ANTI-ICING	530	240	520	235	742	336	570	258
AUXILIARY GEAR GROUP	(30)	(14)	(30)	(14)	(30)	(14)	(30)	(14)
MANUFACTURER'S EMPTY WEIGHT	99,770	45,255	101,066	45,843	119,962	54,414	94,685	42,948

TABLE A-10 (CONT)

GROUP WEIGHT SUMMARY

HIGH LIFT CONCEPT	EXTERNALLY BLOWN FLAP		EBF+10% OVERSIZED ENG		MECHANICAL FLAP			
NUMBER OF PASSENGERS	150		150		150			
FIELD LENGTH - FT (m)	3000	914.4	3000	914.4	3000	914.4	4000	1219
UNITS	lb	kg	lb	kg	lb	kg	lb	kg
OPERATIONAL ITEMS	(2,840)	(1,288)	(2,834)	(1,285)	(2,978)	(1,351)	(2,866)	(1,300)
PILOT & CO PILOT @ 170# ea (77.1 kg ea	340	154	340	154	340	154	340	154
CABIN ATTENDANTS @ 130# ea (59.0 kg ea)	520	236	520	236	520	236	520	236
CREW LUGGAGE & BRIEFCASES	170	77	170	77	170	77	170	77
PASSENGER SERVICE ITEMS								
FOOD, BEVERAGE, & GALLEY EQUIPMENT	231	105	231	105	231	105	231	105
CABIN SUPPLIES & LAVATORY SUPPLIES	439	199	439	199	439	199	439	199
POTABLE WATER	375	170	375	170	375	170	375	170
ENGINE OIL	195	89	195	89	195	89	195	89
EVACUATION SLIDES	225	102	225	102	225	102	225	102
UNUSABLE FUEL	345	156	339	153	483	219	371	168
MANUFACTURER EMPTY WEIGHT	99,770	45,255	101,066	45,843	119,962	54,414	94,685	42,948
OPERATIONAL ITEM WEIGHT	2,840	1,288	2,834	1,285	2,978	1,351	2,866	1,300
OPERATIONAL EMPTY WEIGHT	102,610	46,543	103,900	47,128	122,940	55,765	97,551	44,248
MISSION PAYLOAD WEIGHT*	30,000	13,608	30,000	13,608	30,000	13,608	30,000	13,608
MISSION ZERO FUEL WEIGHT	132,610	60,151	133,900	60,736	152,940	69,373	127,551	57,856
MISSION FUEL WEIGHT**	16,390	7,434	17,300	7,847	19,360	8,781	16,049	7,280
STOL TAKEOFF GROSS WEIGHT	149,000	67,585	151,200	68,583	172,300	78,154	143,600	65,136

TABLE A-10 (CONT)
GROUP WEIGHT SUMMARY

HIGH LIFT CONCEPT	EXTERNALLY BLOWN FLAP		EBF+10% OVERSIZED ENG		MECHANICAL FLAP			
NUMBER OF PASSENGERS	150		150		150			
FIELD LENGTH - FT (m)	3000	914.4	3000	914.4	3000	914.4	4000	1219
UNITS	lb	kg	lb	kg	lg	kg	lg	kg
COST WEIGHTS								
MFR EMPTY WEIGHT	99,770	45,255	101,066	45,843	119,962	54,414	94,685	42,948
LESS: ROLLING ASSY	-1,660	-753	-1,682	-763	-1,916	-869	-1,597	-724
DRY ENGINES	-10,795	-4,897	-11,848	-5,374	-8,877	-4,027	-7,774	-3,526
COST WEIGHT	87,315	39,605	87,536	39,706	109,169	49,518	85,314	38,698
LESS ITEMS PECULIAR TO AMPR								
STARTERS	-105	-48	-105	-48	-105	-48	-105	-48
AUX POWER UNIT	-245	-111	-245	-111	-245	-111	-245	-111
INSTRUMENTS	-631	-286	-631	-286	-631	-286	-631	-286
BATTERY AND A.C. SUPPLY	-561	-254	-561	-254	-511	-231	-511	-231
AVIONICS (BLK BOXES)	-1,074	-487	-1,074	-487	-1,074	-487	-1,074	-487
AIRCONDITION UNIT	-319	-145	-319	-145	-319	-145	-319	-145
HYDRAULICS (DROP-OUT GEN)	-145	-66	-145	-66	-145	-66	-145	-66
AMPR WEIGHT	84,235	38,208	84,456	38,309	106,139	48,144	82,284	37,324

TABLE A-11

DIMENSIONAL AND STRUCTURAL DATA

HIGH LIFT CONCEPT / NUMBER OF PASSENGERS	EXTERNALLY BLOWN FLAP 150		EBF+10% OVERSIZED ENG 150		MECHANICAL FLAP 150			
FIELD LENGTH - FT (m)	3000	914.4	3000	914.4	3000	914.4	4000	1219
DESIGN CRUISE MACH NO.	.69	.69	.71	.71	.74	.74	.77	.77
MISSION RANGE - S-MILES (km)	575	926	575	926	575	926	575	926
CONFIGURATION DATA								
WING LOADING - LBS/FT^2 (kg/m^2)	102	498	108	527	60.5	295.4	85.5	417.4
ENGINE DESIGNATION	PD287-3	PD287-3	PD287-3	PD287-3	5.9/1.57	5.9/1.57	5.9/1.57	5.9/1.57
SLS THRUST (UNINST)/TOGW	.490	.490	.530	.530	.356	.356	.374	.374
SLS THRUST (UNINST)/ENG - LB (N)	18,250	81,180	20,040	89,142	30,680	136,471	26,870	119,524
NO. OF ACOUSTIC RINGS (INLET/EXH)	0	0	0	0	0	0	0	0
NO. OF WING MTD ENG/AIRPL	4	4	4	4	2	2	2	2
MISSION FUEL WEIGHT/TOGW	.1100	.1100	.1147	.1147	.112	.112	.112	.112
DIMENSIONAL DATA								
WING:								
AREA - FT^2 (m^2)	1,461	135.7	1,400	130.1	2,848	264.6	1,679	156.0
MAC LENGTH - IN (cm)	177.8	451.6	174.1	442.2	238.1	604.8	182.8	464.4
SPAN LENGTH - FT (m)	108.1	32.94	105.8	32.25	157.4	47.98	120.9	36.84
ASPECT RATIO	8.0	8.0	8.0	8.0	8.7	8.7	8.7	8.7
TAPER RATIO	.3	.3	.3	.3	.3	.3	.3	.3
SWEEP BACK AT 25% CHORD - DEGREE	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
THEO ROOT CHORD LENGTH - IN (cm)	249.5	633.7	244.2	620.3	334.0	848.4	256.5	651.4
THEO ROOT CHORD MAX t - IN (cm)	41.5	105	40.3	102	55.1	140.0	42.3	107.5
THICKNESS BREAK CHORD LENGTH - IN (cm)	188.4	478.5	184.4	468.3	252.2	640.6	193.6	491.8
THICKNESS BREAK CHORD MAX t - IN (cm)	26.1	66.3	25.4	64.6	34.8	88.4	26.7	67.9
THEO TIP CHORD LENGTH - IN (cm)	74.8	190	73.3	186	100.2	254.5	76.9	195.4
THEO TIP CHORD MAX t - IN (cm)	9.0	23	8.9	23	12.1	30.8	9.31	23.6
LOC OF T/C BREAK - FRACTION OF b/2	.35	.35	.35	.35	.35	.35	.35	.35

TABLE A-11 (CONT)

DIMENSIONAL AND STRUCTURAL DATA

HIGH LIFT CONCEPT NUMBER OF PASSENGERS FIELD LENGTH - FT (m)	EXTERNALLY BLOWN FLAP 150		EBF+10% OVERSIZED ENG 150		MECHANICAL FLAP 150			
	3000	914.4	3000	914.4	3000	914.4	4000	1219
WING (CONTINUED)								
AREAS: FT^2 (m^2)								
AILERONS (AFT OF HINGE LINE)	65	6.0	61	5.7	112	10.4	59	5.5
LEADING EDGE FLAP	81	7.5	78	7.2	0	0	0	0
TRAILING EDGE FLAP	333	30.9	318	29.5	674	62.7	370	34.4
SLAT	86	8.0	82	7.6	355	32.9	209	19.4
SPOILER	143	13.3	136	12.7	294	27.4	161	15.0
HORIZONTAL TAIL								
AREA - FT^2 (m^2)	419	38.9	421	39.1	654	60.8	339	31.5
MAC - LENGTH - IN (cm)	115.1	292.4	115.4	293.0	143.9	365.4	103.5	262.8
SPAN - LENGTH - FT (m)	45.8	13.9	45.9	14.0	57.2	17.4	41.1	12.5
ASPECT RATIO	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
TAPER RATIO	.45	.45	.45	.45	.45	.45	.45	.45
SWEEP BACK AT 25% CHORD - DEGREE	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
THEO ROOT CHORD LENGTH - IN (cm)	151.5	384.8	151.8	385.7	189.4	481.0	136.2	345.9
THEO ROOT CHORD MAX t - IN (cm)	15.2	38.6	15.2	38.6	18.9	48.1	13.6	34.6
THEO TIP CHORD LENGTH - IN (cm)	68.2	173	68.3	173.6	85.2	216.4	61.3	155.7
THEO TIP CHORD MAX t - IN (cm)	6.8	17	6.8	17.4	8.5	21.6	6.1	15.6
HORIZ TAIL ARM - IN (cm)	885	2,248	885	2,248	800	2,032	738	1,875
HORIZ TAIL VOLUME	1.426	1.426	1.528	1.528	.772	.772	.814	.814
ELEV. AREA (AFT OF HL) - FT^2 (m^2)	140	13.0	141	13.1	156	14.5	79	7.3
L.E. SLAT AREA - FT^2 (m^2)	57	5.3	57	5.3	0	0	0	0

TABLE A-11 (CONT)

DIMENSIONAL AND STRUCTURAL DATA

HIGH LIFT CONCEPT	EXTERNALLY BLOWN FLAP		EBF+10% OVERSIZED ENG		MECHANICAL FLAP			
NUMBER OF PASSENGERS	150		150		150			
FIELD LENGTH - FT (m)	3000	914.4	3000	914.4	3000	914.4	4000	1219
VERTICAL TAIL								
AREA - FT^2 (m^2)	319	29.6	319	29.6	565	52.5	317	29.4
MAC - LENGTH - IN (cm)	205.3	521.5	205.3	521.5	316.2	803.3	236.7	601.3
SPAN - LENGTH - FT (m)	18.7	5.70	18.7	5.7	21.5	6.6	16.1	4.9
ASPECT RATIO	1.1	1.1	1.1	1.1	.82	.82	.82	.82
TAPER RATIO	.8	.8	.8	.8	.8	.8	.8	.8
SWEEP BACK AT 25% CHORD - DEGREE	40	40	40	40	40	40	40	40
THEO ROOT CHORD LENGTH - IN (cm)	227.2	577.1	227.2	577.1	349.9	888.9	262.0	665.4
THEO ROOT CHORD MAX t - IN (cm)	25.0	63.5	25.0	63.5	38.5	97.8	28.8	73.2
THEO TIP CHORD LENGTH - IN (cm)	181.7	461.5	181.7	461.5	280.0	711.1	209.6	532.3
THEO TIP CHORD MAX t - IN (cm)	20.0	50.8	20.0	50.8	30.8	78.2	23.1	58.6
VERT TAIL ARM - IN (cm)	735	1,867	735	1,867	600	1,524	600	1,524
VERT TAIL VOLUME	.1238	.1238	.1320	.1320	.063	.063	.078	.078
RUD AREA (AFT OF HL) - FT^2 (m^2)	115	10.7	115	10.7	154	14.3	90	8.4
FUSELAGE								
LENGTH - MAX FUSELAGE - IN (cm)	1500	3810	1500	3810	1525	3874	1475	3747
DEPTH - MAX FUSELAGE - IN (cm)	180	457	180	457	180	457	180	457
WIDTH - MAX FUSELAGE - IN (cm)	180	457	180	457	180	457	180	457
WETTED AREA - FUSELAGE* - FT^2 (m^2)	5127	476.3	5127	476.3	5205	483.5	5009	465.3
ALIGHTING GEAR								
TYPE	TRICYCLE	TRICYCLE	TRICYCLE	TRICYCLE	TRICYCLE	TRICYCLE	TRICYCLE	TRICYCLE
LENGTH - OLEO EXTENDED - IN (cm)	100	254	100	254	102	259	85	216
MAX OLEO TRAVEL - IN (cm)	27	69	27	69	27	69	30	76

* To Theoretical Loft Lines - No Cutouts, No Pods.

TABLE A-11 (CONT)

DIMENSIONAL AND STRUCTURAL DATA

HIGH LIFT CONCEPT	EXTERNALLY BLOWN FLAP		EBF+10% OVERSIZED ENG		MECHANICAL FLAP			
NUMBER OF PASSENGERS	150		150		150			
FIELD LENGTH - FT (m)	3000	914.4	3000	914.4	3000	914.4	4000	1219
FUEL SYSTEM (USABLE) - PER AIRPLANE	(8,080)	(30.58)	(7,530)	(28.50)	(22,220)	(84.10)	(10,000)	(37.85)
OUTER WING - NO. OF TANKS/GAL (m^3)	4/5,830	4/22.07	4/5,400	4/20.44	4/17,715	4/67.05	4/7,440	4/28.16
CENTER WING - NO. OF TANKS/GAL (m^3)	1/2,250	1/8.516	1/2,130	1/8.06	1/4,505	1/17.05	1/2,560	1/9.69
STRUCTURAL DATA - CONDITION								
STOL TAKEOFF G.W. - LBS (kg)	149,000	67,585	151,240	68,601	172,300	78,154	143,600	65,136
FUEL IN WING - LBS (kg)	16,390	7,434	17,340	7,865	19,360	8,781	16,049	7,280
STRESS G.W. - LBS (kg)	149,000	67,585	151,240	68,601	172,300	78,154	143,600	65,136
ULTIMATE LOAD FACTOR	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
STOL LANDING G.W. - LBS (kg)	149,000	67,585	151,240	68,601	172,300	78,154	143,600	65,136
MAX. G.W. WITH ZERO FUEL - LBS (kg)	132,610	60,151	133,900	60,736	152,940	69,373	127,551	57,856
LIMIT A/C LDG SINK SPEED - FT/SEC(m/SEC	15	4.6	15	4.6	15	4.6	15	4.6
WING LIFT FOR LDG DES COND - %	100	100	100	100	100	100	100	100
PRESS CABIN-ULT DES DIFF-LBS/IN^2(kg/cm^2	11.19	.7759	11.19	.7759	11.19	.7759	11.19	.7759

design aircraft is identical to that tabulated in Appendix E, Vol. II of Reference 1, but is reproduced here for easy comparison to the other final designs. The mechanical-flap configurations are lighter than those in the Reference 1 study by reason of a lighter weight engine, elimination of sound suppression rings, short in lieu of long duct nacelle, a less cantilevered pylon, shorter chord flap, and lighter wing box weight. The decrease in wing box weight results from elimination of flutter penalty due to lower aspect ratio and more box chord, lighter flap attach bulkheads because of shorter chord flap, and lighter pylon attach bulkheads due to a further aft engine placement on the wing.

APPENDIX B

This appendix contains results of propulsion studies for the EBF aircraft performed during the "Study of Quiet Turbofan STOL Aircraft for Short-Haul Transportation" and previously reported in Reference 1. Pertinent information has been included here for convenient reference.

B.1 Propulsion Installation

The externally-blown-flap engine installation is shown in Figure B-1. The drawing is of a 20,000 pound (89,000 N) thrust Allison PD287-3 engine, which has a variable-pitch fan with a pressure ratio of 1.25. The thrust level of the drawing was selected prior to final aircraft sizing and does not necessarily match the engine size on the aircraft.

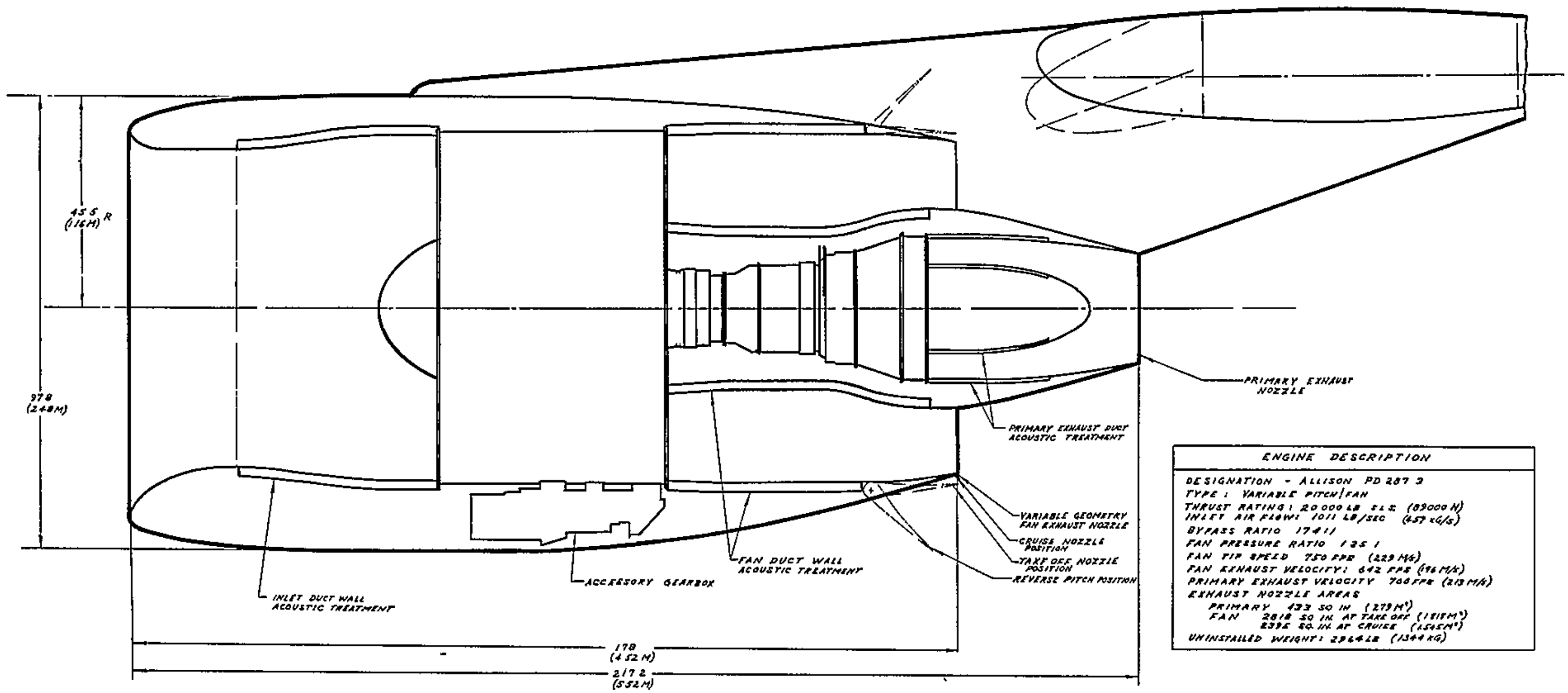
B.1.1 Engine/Airframe Interrelation - The engine installation is shown matched to a wing cross section corresponding to the 50 percent semi-span cut of an 1800 square foot (167 m^2) wing with 7.0 aspect ratio, 0.3 taper ratio, and 25 degrees (.436 rad.) of sweep at the quarter chord. These values were derived from previous studies and test experience as being typical for meeting externally-blown-flap wing requirements for high lift with low weight.

The nacelle is positioned relative to the wing horizontally by locating the fan exhaust plane forward of the wing L.E.; the vertical position is fixed by locating the top of the fan exhaust in the same horizontal plane as the lowest extremity of the drooped-wing leading edge section.

B.1.2 Engine Inlet Geometry - The engine inlet throat area is sized to give an average throat Mach number of 0.6 at takeoff power at sea level static

VARIABLE-PITCH FAN ENGINE INSTALLATION

EXTERNALLY BLOWN FLAP AIRCRAFT



PR3-STOL-1641B

FIGURE B-1.

conditions. The inlet is configured with a leading edge lip thickness that varies from 11 percent at the top to a maximum of 20 percent at the bottom. This lip design is based on test data to have acceptable inlet distortion levels with crosswind and at the high local flow angles of attack due to wing induced upwash. The inlet length is determined by the length of acoustical treatment necessary to attain the desired level of noise attenuation.

B.1.3 Nacelle External Shape - The maximum nacelle radii are sized to provide engine fan case clearance and to accommodate a fan exhaust duct with a Mach number of 0.45 and the necessary acoustic wall treatment. The nacelle/fan case clearance includes a volume allocation for the engine accessories and engine-mounted airframe system components such as C.S.D./generators, hydraulic pumps, and pneumatic system controls and ducting. Size estimates of these components were based upon aircraft requirements using data from the DC-8, DC-9, and DC-10.

The fan and core cowl afterbody lengths are based on test data to minimize length consistent with avoiding compressibility drag.

B.1.3.1 Exhaust Duct Geometry - The fan duct flow area is sized to maintain a duct Mach number below 0.45 through the acoustically lined duct between the engine fan case and the leading edge of the variable area exhaust nozzle vanes. The duct length was determined by acoustic requirements.

The variable fan area, thrust reversing, and accessibility features of this engine installation are the same as discussed in Section 4.2.4.

B.2 Installed Engine Performance

Installed engine performance data were generated by correcting the engine manufacturer's reference engine performance values for the effects of installing the engine on the airplane.

The installation effects are:

- o Inlet and exhaust system total pressure loss, including the applicable losses due to acoustic treatment.
- o Exhaust system nozzle performance differences relative to that included in the reference performance.
- o Scrubbing drag on those external surfaces that are washed by the engine exhaust flow.
- o Engine compressor airbleed and mechanical power extraction to supply the airplane accessory system requirements.
- o Fan airbleed to cool the compressor airbleed to acceptable values.

B.2.1 Inlet Pressure Loss. - The inlet total pressure loss, shown in Table B-1, is calculated as flat-plate skin-friction loss on all surfaces. A friction coefficient, 40 percent higher than that for smooth surfaces, was assumed for all acoustically treated surfaces. The increase in loss at high mass flow ratios (takeoff condition) is due to high local velocities near the inlet leading edge at static conditions and low forward speeds.

B.2.2 Fan Duct and Nozzle Losses. - The exhaust system losses were evaluated using skin friction calculations for smooth and for acoustically treated walls in the same manner as for the inlet.

B.2.3 External Aerodynamic Losses. - The drag of the isolated nacelle at the typical cruise condition is included in the installed engine performance. The skin friction coefficient used to calculate drag is a function of the local Reynolds number. Local Reynolds number is calculated for both the freestream cruise condition and the fully expanded exhaust flows for both fan and primary exit conditions. Drag coefficients, D/q, are then calculated for the nacelle and pylon in the three flow regimes; freestream, fan nozzle discharge, and primary nozzle discharge. Depending on the nacelle configuration, the fan cowl and part of the pylon are exposed to freestream flow, while parts of the pylon and engine core cowl are exposed to fan nozzle discharge. Also, parts of the pylon may be exposed to primary nozzle discharge flow. Drag values for these three flow regimes are shown in Table B-1.

B.2.4 Airbleed and Mechanical Power Extraction. - Engine compressor airbleed is used for air conditioning and pressurizing the flight deck and crew compartment. Precoolers located in the pylons use fan bleed to cool the compressor airbleed. Airbleed requirements are based on 14 CFM (.0066 m^3/s) per passenger, where flow density is calculated using the DC-10 maximum cabin pressure schedule and a temperature of 70°F (21°C).

Mechanical power extraction is based on a statistical study of system requirements in several modes of flight. For all configurations, 150 HP (112 kW) per airplane was used for takeoff conditions, while 110 HP (82 kW) per airplane was used for cruise conditions.

B.3 Installation Loss Analyses

Table B-1 is a summary of the installation effects on engine performance at takeoff and cruise conditions for the EBF nacelle configuration considered in the study. The losses in each case are referenced to the required uninstalled thrust, Fn_o. The uninstalled sea level static takeoff thrust value for the selected engine size is denoted by Fn_{REF}.

B.4 Installed Propulsion System Performance Data

Installed propulsion system performance data for all significant aircraft operating conditions are shown in Figures B-2 and B-3. Performance for takeoff (maximum power) is presented in terms of gross thrust and ram drag in Figure B-2. Installed fuel flow for any condition can be obtained from Figure B-3 which show the generalized fuel flow parameter as a function of net thrust and Mach number.

TABLE B-1
INSTALLATION LOSSES

Configuration & Engine	Flight Condition	Alt	M_o	T_o	F_{N_o}	W_{f_o}	Loss Summary	Inlet Recovery $\frac{P_{T2}}{P_{TO}}$	Air Conditioning Bleed	Power Extraction	$\frac{\Delta P_{T_{DUCT}}}{P_T}$	$\frac{\Delta P_{T_{PRI}}}{P_T}$	$C_{V_{DUCT}}$	$C_{V_{PRI}}$	Drags			F_{N_C} $\Sigma \frac{\Delta F_N}{F_N}$	W_{f_C} $\Sigma \frac{\Delta W_f}{W_f}$
															D_o	D_{FAN}	D_{PRI}		
E.B.F. PD287-3	T.O.	0	.117	95°F (35°C)	14,749 lb (65.606 kN)	4,284 lb/hr (.5398 kg/s)	Amount	.9947	.62 lb/sec (.281 kg/sec	37.5 HP (28. kW)	.0073	.0072	.978	.977	26 lb (118 N)	99 lb (443 N)	8 lb (36 N)	13,581 lb (60.411 kN)	4,212 lb/hr (.5307 kg/s)
$F_{N_{REF}}$ = 18,260 lb (81.224 kN)							$\Delta F_N/F_N$	.023	.019	.001	.016	.003	.008	≈0.0	.002	.007	0.0	.079	-
							$\Delta W_f/W_f$	.005	.012	≈0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	0.17
	Cruise	20,000 Ft (6096 m)	.7	STD	4,210 lb (18.727 kN)	2,413 lb/hr (.304 kg/s)	Amount	.996	.62 lb/sec (.281 kg/sec)	27.5 HP (20.5 kW)	.0064	.008	.978	.977	436 lb (1939 N)	120 lb (534 N)	6 lb (27 N)	3,168 lb (14.09 kN)	2,359 lb/hr (.297 kg/s)
							$\Delta F_N/F_N$	.022	.040	-.003	.022	.005	.029	≈0.0	.104	.028	.001	.248	-
							$\Delta W_f/W_f$	.004	.016	.002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	.022

NOTE: 1) Not shown is the effect of pre-cooling fan bleed which is negligible.

2) The uninstalled value for $C_{v_{duct}}$ and $C_{v_{pri}}$ is .985

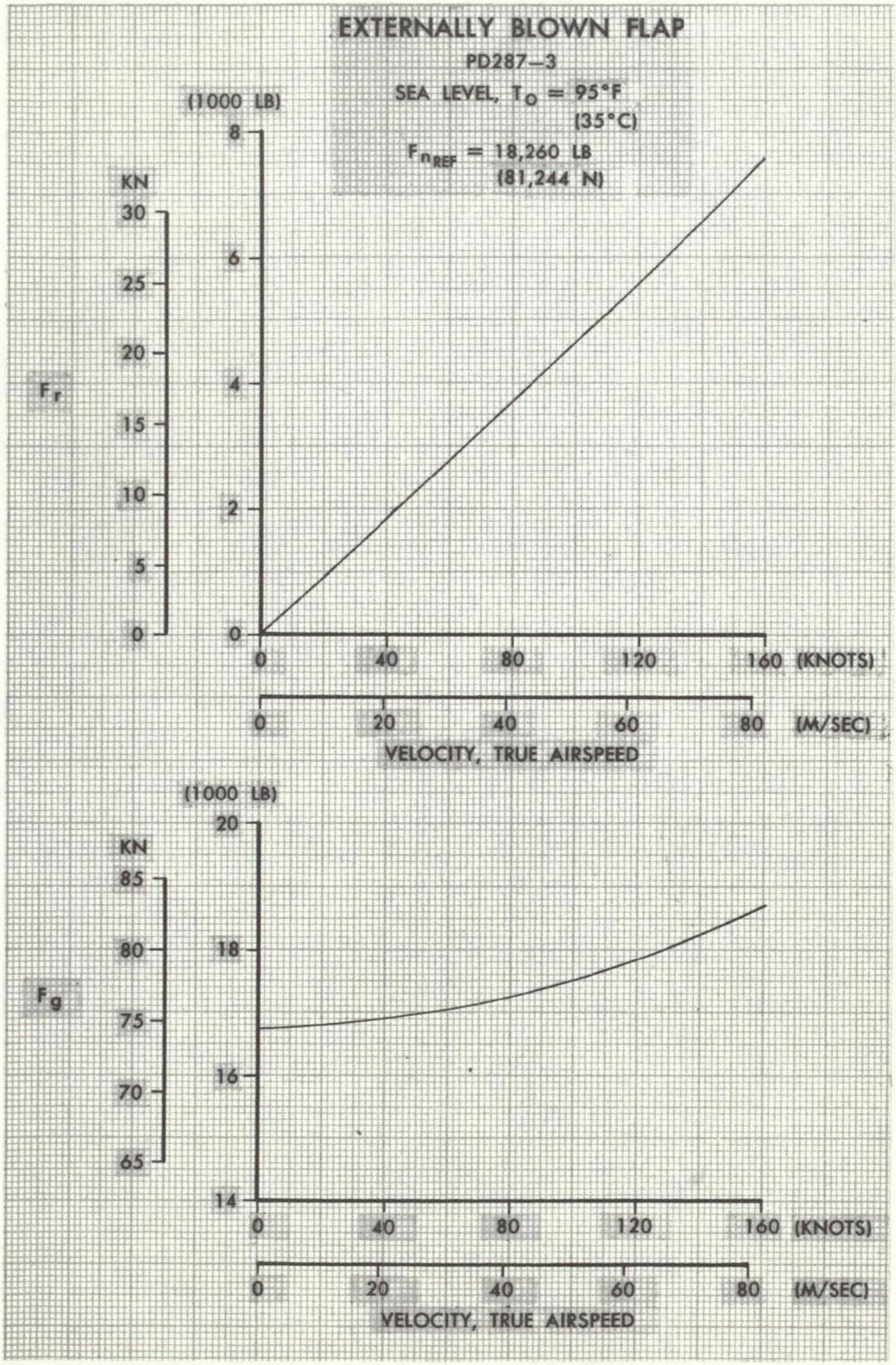


FIGURE B-2. GROSS THRUST AND RAM DRAG AT TAKEOFF POWER

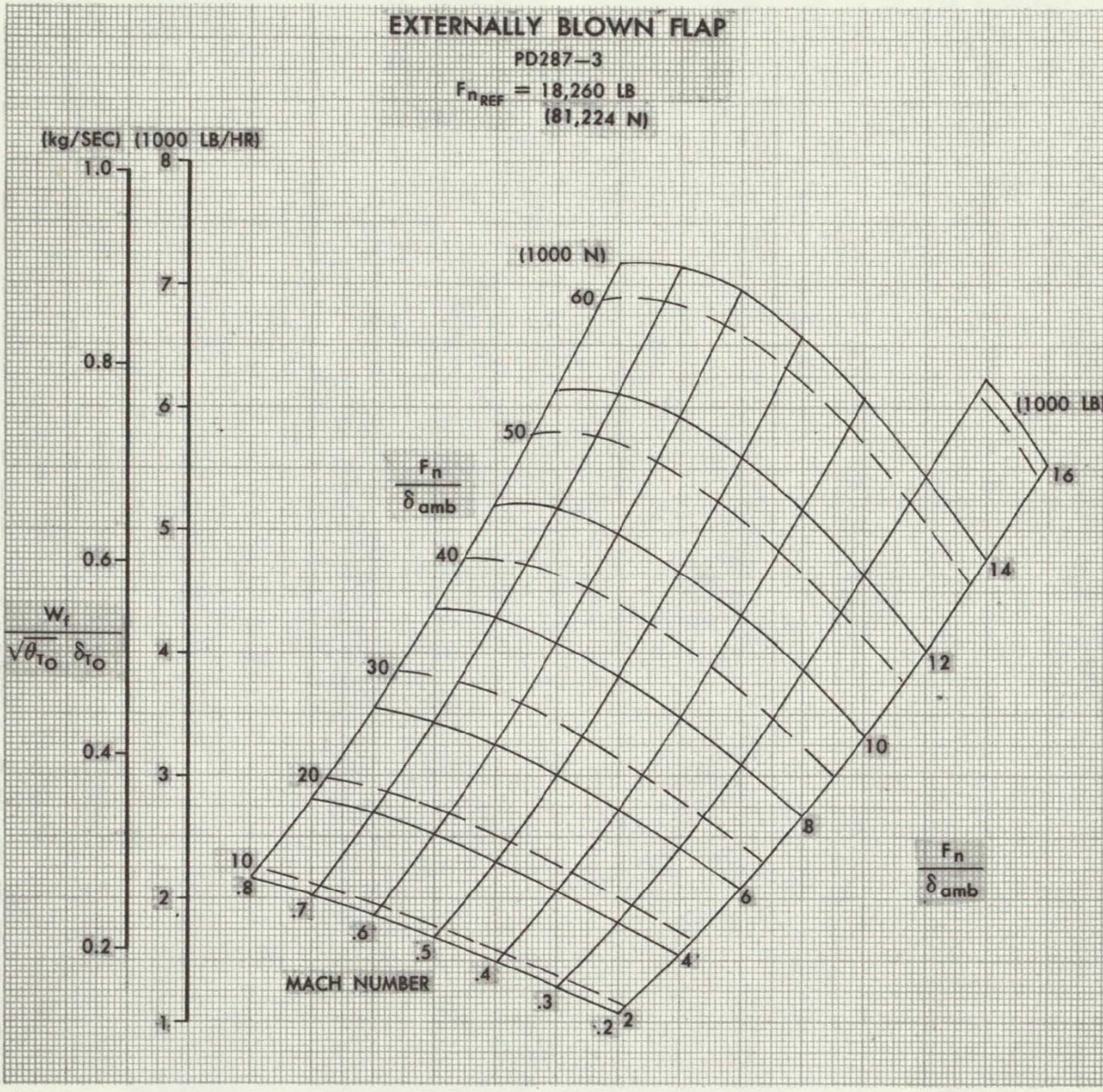


FIGURE B-3. GENERALIZED NET THRUST AND FUEL FLOW

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APPENDIX C

C. ACOUSTICS

C.1 Source Noise Prediction Methods

C.1.1 Prediction of Engine Source Noise - The Douglas Quick Response Engine Source Noise (QRESN) prediction procedure was developed to provide a quick-response method of estimating engine component and total noise on a PNL basis. The procedure is based on measured static test data (NASA Fan A and Fan C, JT3D, JT8D, JT9D and CF6), and flyover noise data (DC-8, DC-9, and DC-10).

Noise from turbofan engines consist of turbomachinery noise, combustion noise, and jet exhaust noise. Noise radiated from the engine inlet is a maximum in the forward quadrant at angles between 40 degrees (.70 rad) and 80 degrees (1.40 rad) relative to the inlet. The maximum values of noise from the fan discharge, turbine discharge, and jet noise sources occur in the aft quadrant at angles between 100 degrees (1.75 rad) and 140 degrees (2.44 rad) from the inlet. Figure C-1 presents a typical high bypass ratio engine noise source breakdown showing Perceived Noise Level (PNL) as a function of angle from the inlet.

The QRESN procedure determines the maximum PNL for each noise source based on engine cycle parameters. The QRESN prediction procedure is summarized in Figure C-2. The engine cycle parameters required to estimate the component noise levels are as follows:

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NOISE SOURCE BREAKDOWN

HIGH BYPASS RATIO ENGINE

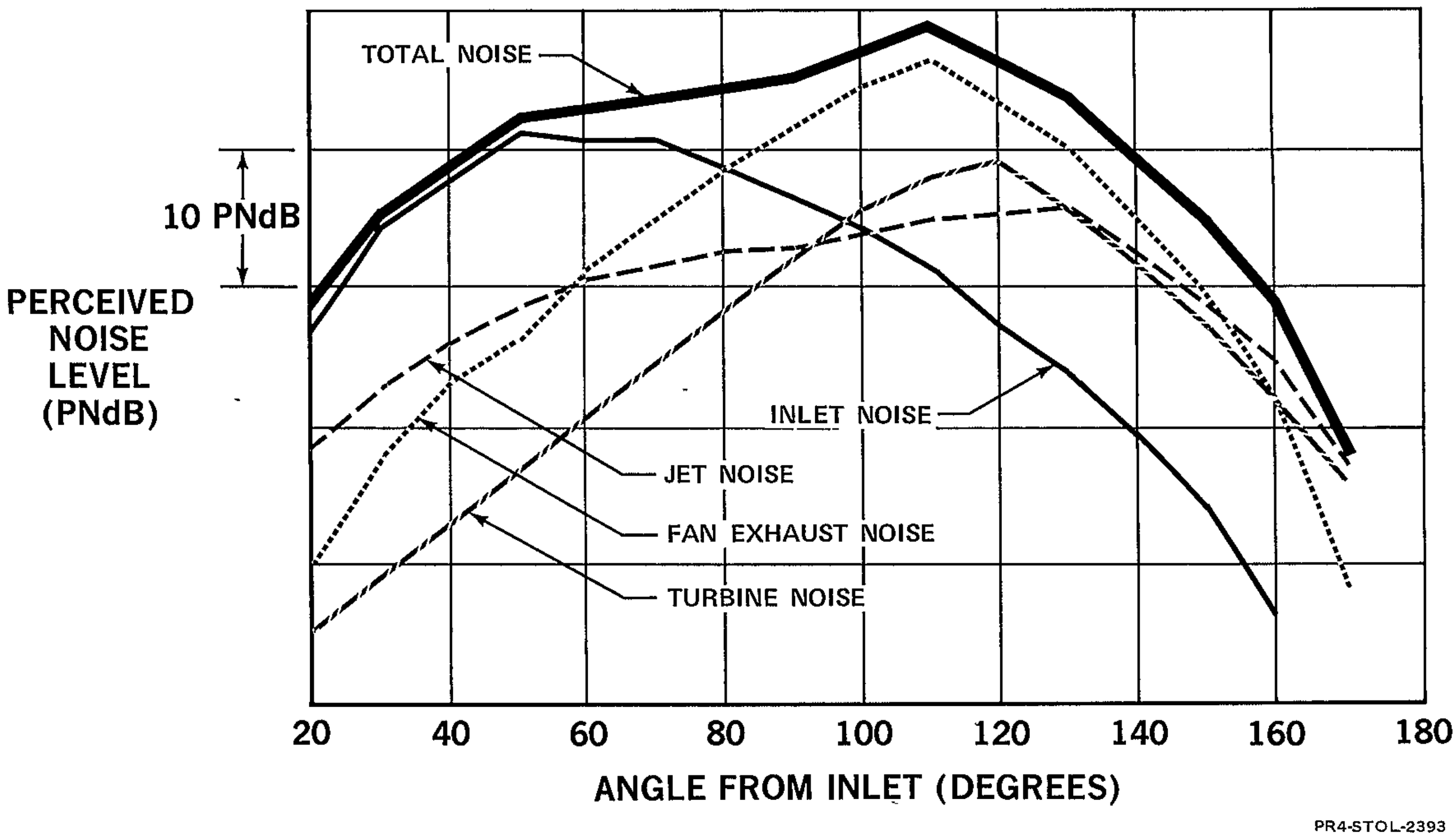


FIGURE C-1.

NOISE PREDICTION PROCEDURE

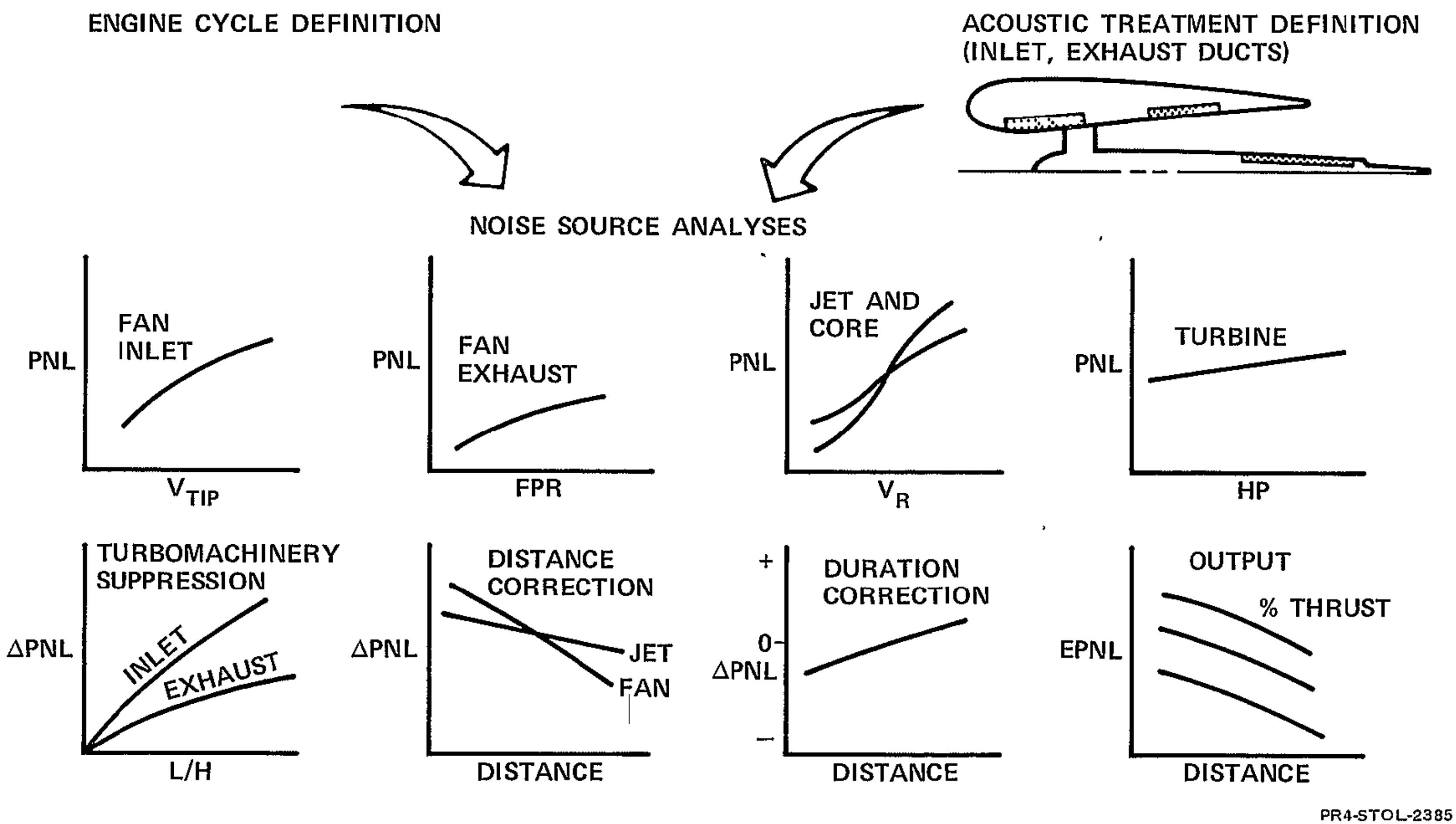


FIGURE C-2.

ENGINE PARAMETERS	PNL FAN INLET	PNL FAN EXHAUST	PNL JET	PNL CORE	PNL TURBINE
Fan Tip Speed	X				
Inlet Flow Rate	X	X			
Fan Pressure Ratio		X			
Fan Exit Velocity			X		
Fan Exit Area			X		
Fan Exhaust Flow Rate			X		
Primary Exit Velocity			X	X	
Primary Exit Area			X	X	
Primary Flow Rate			X	X	X

Using the cycle parameters applicable to each noise source the individual component noise levels are calculated and the maximum PNL on a sideline produced by all the noise sources is determined by combining logarithmically the contributions from all sources peaking in the aft quadrant. The contribution of inlet noise to the total aft quadrant noise level was assumed to be 9 PNdB less than the peak inlet noise level in the forward quadrant (Ref. Figure C-1). A similar technique is also used in determining the maximum PNL on a sideline, produced by the noise sources in the inlet quadrant. Adjustments in terms of PNdB for ground attenuation, the number of engines, distance from the noise source, technology factors, and turbomachinery suppression (L/H), are made to the component noise source noise levels prior to the summation process.

The effective perceived noise level (EPNL) is calculated as a function of the maximum inlet or exhaust PNL and corrected for duration at a specific sideline distance from the noise source. This procedure is used to generate plots of EPNL as a function of distance and power setting.

Figure C-3 shows the correlation between measured flyover noise levels for the DC-10 (with CF6-6 engines) and predicted noise levels using the DAC quick prediction procedure.

C.1.2 <u>Prediction of Powered-Lift-System Noise</u> - The procedure used to evaluate the noise from powered-lift systems (PLS) was the Quick Response Powered Lift System (QRPLS) procedure which was developed by Douglas Aircraft in 1973.

A schematic of the QRPLS procedure is shown in Figure C-4. The calculation of PLS noise was determined by accounting for the effects of:

- flap deflection, δ_F
- effective nozzle exit velocity, V_{EFF}
- distance to the aircraft, SR
- exhaust temperature, T_{EXIT}
- effective nozzle diameter, D_{EFF}, and
- ambient aircraft velocity, V_{AMB}

This procedure can be utilized to determine both EPNL and PNL for both lower-surface blown (LSB) and upper-surface blown (USB) flaps. The QRPLS procedure was formulated from a Douglas computer program for predicting PLS noise. The parameters of this program were varied systematically to determine their relative effect on a PNL and EPNL basis. This resulted in the PLS noise correlation parameters specified above.

COMPARISON OF DC-10-10 FLYOVER NOISE LEVELS

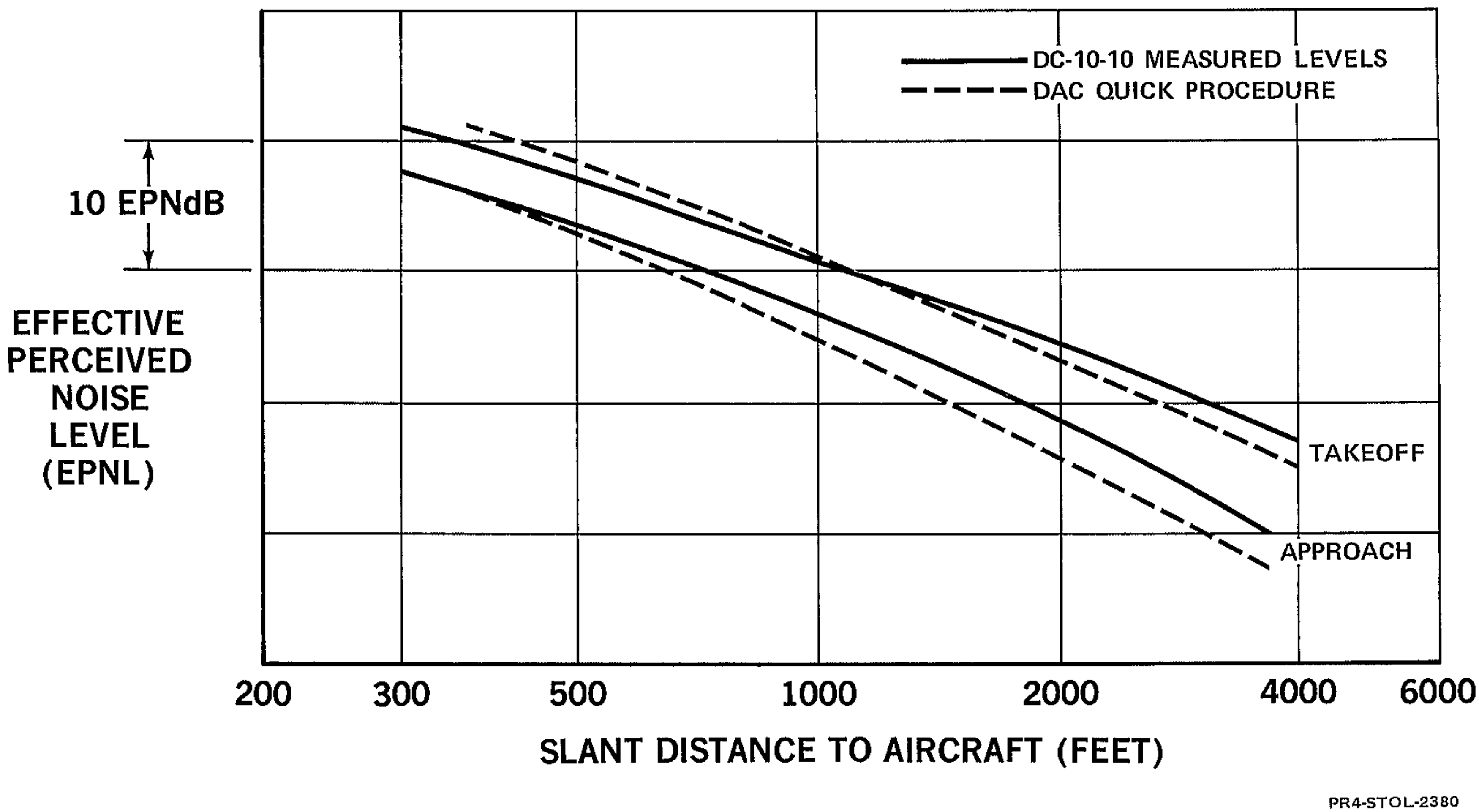
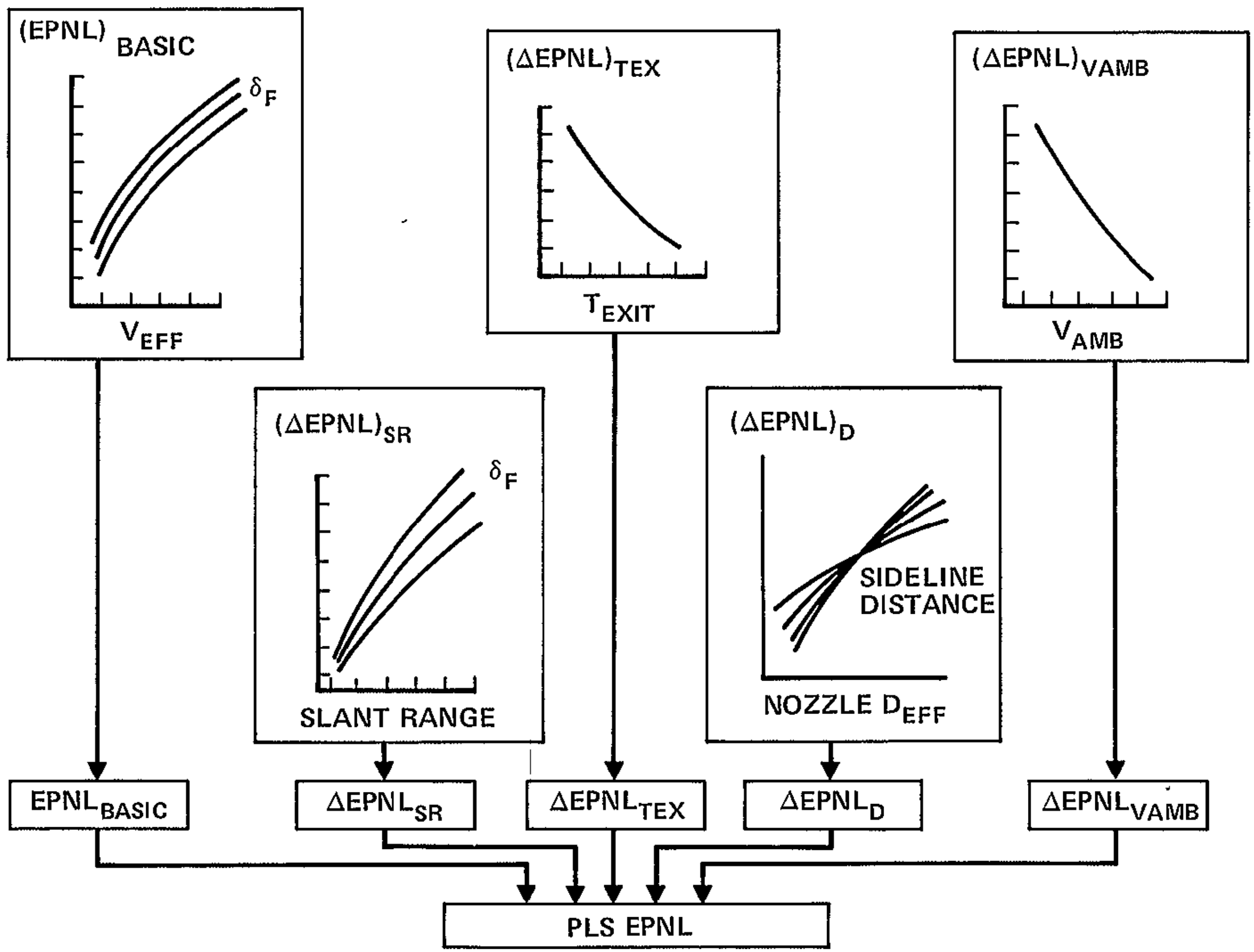


FIGURE C-3.

QUICK RESPONSE PLS NOISE PREDICTION PROCEDURE (LSB AND USB)



PR4-GEN-24586

FIGURE C-4.

The range of input parameters which were evaluated are as follows:

- flap deflection from 0 to 60 degrees
- effective nozzle exit velocities from 400 to 1200 ft/sec
- effective nozzle exhaust temperatures from 519 to 2000 ^{o}F
- ambient temperature from 480 to 560 ^{o}F
- effective nozzle diameter from 3 to 7 feet
- sideline distances from 0 to 10,000 feet
- altitudes from 100 to 10,000 feet

In addition, the following adjustments were applied to the predicted PLS values:

- 10 log (number of engines)
- the effect of aircraft forward velocity = -1 dB
- technology relief factor = -3 dB

The QRPLS procedure has been evaluated as having an accuracy of ±1 dB relative to the more extensive Douglas computer program. The computer program, in turn, has predicted full scale, TF-34 PLS noise levels to within ±2 dB of those measured. It is therefore believed that this procedure is a reasonably accurate method for evaluating PLS noise levels.

APPENDIX

C.2 Noise Impact Evaluation

This appendix contains a sample computer run using the Aircraft Noise Contour/Community Noise Impact Evaluation (AIFA) Program. The run shown is for the E-150-3000 aircraft and the standard takeoff and approach procedure. The noise impact evaluation is conducted at Orange County Airport.

TABLE OF CONTENTS

E N G I N E   N O I S E   D A T A ,   E P N D B

		P E R C E N T	T H R U S T					
		20.	40.	60.	70.	80.	90.	100.
S	200.	88.9	95.9	100.1	101.8	102.9	104.3	105.6
L	500.	80.7	88.4	93.0	94.9	96.1	97.6	99.0
A	1000.	73.1	80.8	85.4	87.3	88.5	90.0	91.4
N	2000.	65.4	73.2	77.7	79.7	81.0	82.2	83.7
T	4000.	55.8	63.8	68.6	70.6	71.8	73.4	74.9
R								
A								
N								
G								
E								
REF VEL		100.0	100.0	100.0	100.0	100.0	100.0	100.0

FAN AREA = 19.60 SQ FT

PRIMARY AREA = 3.00 SQ FT

TOTAL AREA = 22.60 SQ FT

NOZZLE DIAMETER = 5.36 FT

T E M P E R A T U R E   A N D   V E L O C I T Y   D A T A

PERCENT THRUST	VELOCITY, FT/SEC FAN	VELOCITY, FT/SEC PRIMARY	TEMPERATURE, DEG R FAN	TEMPERATURE, DEG R PRIMARY
20.	290.0	195.0	545.0	1230.0
40.	420.0	330.0	555.0	1310.0
60.	510.0	465.0	560.0	1453.0
70.	550.0	525.0	566.0	1510.0
80.	588.0	585.0	570.0	1550.0
90.	623.0	645.0	575.0	1590.0
100.	655.0	705.0	576.0	1636.0

FLAP NOISE, EPNL-10LOG(A)

SIDELINE DISTANCE 0. FT

EXHAUST VELOCITY, FT/SEC

		400.0	500.0	600.0	700.0	800.0	900.0	1000.0	1100.0	1200.0
F	0.0	69.90	77.90	83.90	89.10	93.40	97.40	100.60	103.60	106.30
L	30.0	76.40	83.90	89.90	95.10	99.40	103.40	106.90	109.60	112.40
A	60.0	81.50	69.10	95.10	100.10	104.60	108.40	111.70	114.80	117.40
P										

CORRECTION FOR DISTANCE AND VIEW ANGLE

SLANT RANGE, FT

		100.	200.	500.	1000.	2000.	3000.
F	0.0	0.0	-3.20	-7.90	-12.10	-16.90	-20.10
L	30.0	0.0	-3.20	-7.90	-12.10	-16.90	-20.10
A	60.0	0.0	-3.20	-7.90	-12.10	-16.90	-20.10
P							

FLAP NOISE, EPNL-10LOG(A)

SIDELINE DISTANCE 500. FT

EXHAUST VELOCITY, FT/SEC

FLAP	400.0	500.0	600.0	700.0	800.0	900.0	1000.0	1100.0	1200.0
0.0	58.40	66.40	72.90	78.50	83.10	86.90	90.50	93.40	96.10
30.0	64.30	72.40	79.10	84.40	88.80	92.70	95.90	98.90	101.50
60.0	68.90	77.10	83.50	88.60	93.10	96.90	100.10	103.20	105.90

CORRECTION FOR DISTANCE AND VIEW ANGLE

SLANT RANGE, FT

FLAP	510.	710.	1120.	2060.	3040.
0.0	0.0	-1.00	-3.30	-7.30	-10.20
30.0	0.0	-0.60	-2.60	-6.50	-9.30
60.0	0.0	-0.20	-2.00	-5.50	-8.20

FLAP NOISE,EPNL-10LOG(A)

SIDELINE DISTANCE 1519. FT

EXHAUST VELOCITY, FT/SEC

FLAP		400.0	500.0	600.0	700.0	800.0	900.0	1000.0	1100.0	1200.0
F	0.0	51.10	58.90	65.40	70.90	75.60	79.60	83.40	86.40	89.10
L	30.0	57.40	64.90	71.60	77.10	81.90	85.90	89.30	92.10	94.90
A	60.0	61.50	69.60	76.40	81.90	86.40	90.10	93.50	96.40	99.30
P										

CORRECTION FOR DISTANCE AND VIEW ANGLE

SLANT RANGE, FT

FLAP		1520.	1590.	1820.	2510.	3360.
F	0.0	0.0	-0.10	-0.50	-2.40	-4.50
L	30.0	0.0	-0.05	-0.20	-1.90	-3.80
A	60.0	0.0	0.20	0.0	-1.40	-3.10
P						

FLAP NOISE,EPNL-10LOG(A)

SIDELINE DISTANCE 2122. FT

EXHAUST VELOCITY, FT/SEC

FLAP	400.0	500.0	600.0	700.0	800.0	900.0	1000.0	1100.0	1200.0
0.0	48.90	56.40	62.90	68.40	72.90	77.10	80.90	83.90	86.90
30.0	54.70	62.50	69.10	74.70	79.30	83.40	86.90	89.90	92.60
60.0	59.20	67.10	73.80	79.40	84.00	87.90	91.30	94.00	96.90

CORRECTION FOR DISTANCE AND VIEW ANGLE

SLANT RANGE, FT

FLAP	2122.	2180.	2350.	2920.	3680.
0.0	0.0	-0.10	-0.30	-1.60	-3.20
30.0	0.0	0.0	-0.10	-1.00	-2.50
60.0	0.0	0.10	0.10	-0.70	-1.90

F L A P N O I S E , E P N L - 1 0 L O G (A)

S I D E L I N E D I S T A N C E 5000. F T

E X H A U S T V E L O C I T Y , F T / S E C

		400.0	500.0	600.0	700.0	800.0	900.0	1000.0	1100.0	1200.0
F	0.0	43.10	49.90	55.90	61.10	65.60	69.50	73.30	76.40	79.40
L	30.0	46.40	55.60	61.80	67.00	71.90	75.90	79.70	82.90	85.90
A	60.0	52.40	60.20	66.60	71.90	76.70	80.90	84.60	87.70	90.40
P										

C O R R E C T I O N F O R D I S T A N C E A N D V I E W A N G L E

S L A N T R A N G E , F T

		5000.	7500.	10000.
F	0.0	0.0	0.0	0.0
L	30.0	0.0	0.0	0.0
A	60.0	0.0	0.0	0.0
P				

FLAP NOISE,EPNL-10LOG(A)

SIDELINE DISTANCE 10000. FT

EXHAUST VELOCITY, FT/SEC

FLAP		400.0	500.0	600.0	700.0	800.0	900.0	1000.0	1100.0	1200.0
	0.0	39.40	44.40	49.90	54.60	58.90	62.90	66.40	69.40	72.40
	30.0	43.40	49.90	55.40	60.40	64.90	68.90	72.60	75.90	78.60
	60.0	46.90	53.60	59.90	65.10	69.90	73.90	77.90	80.90	83.90

CORRECTION FOR DISTANCE AND VIEW ANGLE

SLANT RANGE, FT

FLAP		10000.	12500.	15000.
	0.0	0.0	0.0	0.0
	30.0	0.0	0.0	0.0
	60.0	0.0	0.0	0.0

FLAP NOISE CORRECTION FOR EXHAUST TEMPERATURE
(INDEPENDENT OF DISTANCE)

TEMPERATURE	DELTA EPNL
519.0	1.3
700.0	0.8
850.0	0.5
1000.0	0.3
1100.0	0.1
1160.0	0.0
1200.0	-0.1
1400.0	-0.3
1600.0	-0.5
1800.0	-0.7
2000.0	-0.9

T A K E O F F   P A R A M E T E R S

DISTANCE FBR ALONG FL PATH	DIST FBR ALONG RUNWY CNTRLINE	ALTITUDE	DISTANCE FROM RUNWY CNTRLINE	AIRCRAFT VELOCITY	PERCENT THRUST	FLAP ANGLE	EXHAUST VELOCITY	EXHAUST TEMPERATURE
0.0	0.0	0.0	0.0	0.0	100.0	20.0	662.9	1171.1
1489.5	1489.5	0.0	0.0	98.7	100.0	20.0	662.9	1171.1
1799.9	1799.9	0.0	0.0	106.1	100.0	20.0	662.9	1171.1
2423.6	2423.6	35.0	0.0	110.5	100.0	20.0	662.9	1171.1
2516.1	2516.1	46.7	0.0	110.5	100.0	20.0	662.9	1171.1
2608.7	2608.7	56.7	0.0	110.8	100.0	20.0	662.9	1171.1
2701.6	2701.6	70.4	0.0	111.1	100.0	20.0	662.9	1171.1
2756.7	2756.7	77.1	0.0	111.4	100.0	20.0	662.9	1171.1
2944.4	2944.4	98.1	0.0	112.4	100.0	20.0	662.9	1171.1
3134.1	3134.1	117.3	0.0	113.5	100.0	20.0	662.9	1171.1
3325.7	3325.7	136.0	0.0	114.6	100.0	20.0	662.9	1171.1
3519.0	3519.0	154.6	0.0	115.6	100.0	20.0	662.9	1171.1
3679.0	3679.0	170.5	0.0	116.3	100.0	20.0	662.9	1171.1
3875.3	3875.3	190.2	0.0	117.5	100.0	20.0	662.9	1171.1
4073.4	4073.4	210.6	0.0	118.5	100.0	20.0	662.9	1171.1
4273.2	4273.2	231.9	0.0	119.5	100.0	20.0	662.9	1171.1
4474.4	4474.4	254.1	0.0	120.4	100.0	20.0	662.9	1171.1
4677.1	4677.1	277.1	0.0	121.3	100.0	20.0	662.9	1171.1
4881.1	4881.1	301.0	0.0	122.1	100.0	20.0	662.9	1171.1
5086.3	5086.4	325.6	0.0	122.9	100.0	20.0	662.9	1171.1
5292.8	5292.8	350.9	0.0	123.6	100.0	20.0	662.9	1171.1
5500.2	5500.2	376.9	0.0	124.2	100.0	20.0	662.9	1171.1
5680.8	5680.8	400.0	0.0	124.8	100.0	20.0	662.9	1171.1
5785.4	5785.4	413.4	0.0	125.1	100.0	18.4	662.9	1171.1
5890.3	5890.3	426.7	0.0	125.6	100.0	16.8	662.9	1171.1
5995.8	5995.8	439.6	0.0	126.2	100.0	15.2	662.9	1171.1
6101.8	6101.8	451.9	0.0	126.9	100.0	13.6	662.9	1171.1
6208.6	6208.6	463.6	0.0	127.7	100.0	12.0	662.9	1171.1
6316.2	6316.2	474.5	0.0	128.6	100.0	10.4	662.9	1171.1
6424.7	6424.7	484.5	0.0	129.7	100.0	8.8	662.9	1171.1
6534.2	6534.3	493.6	0.0	130.8	100.0	7.2	662.9	1171.1
6644.9	6644.9	501.8	0.0	132.1	100.0	5.6	662.9	1171.1
6756.7	6756.7	509.0	0.0	133.4	100.0	4.0	662.9	1171.1
6869.7	6869.7	515.2	0.0	134.9	100.0	2.4	662.9	1171.1
6984.1	6984.1	520.4	0.0	136.5	100.0	0.8	662.9	1171.1
7099.9	7099.9	524.6	0.0	138.1	100.0	-0.0	662.9	1171.1
7335.1	7335.1	533.2	0.0	140.7	100.0	-0.0	662.9	1171.1
7572.9	7573.0	548.3	0.0	141.8	100.0	-0.0	662.9	1171.1
7810.7	7810.8	574.4	0.0	141.8	100.0	-0.0	662.9	1171.1
8047.4	8047.5	609.9	0.0	141.8	100.0	-0.0	662.9	1171.1

TAKEOFF PARAMETERS

DISTANCE FBR ALONG FL PATH	DIST FBR ALONG RUNWY CNTRLINE	ALTITUDE	DISTANCE FROM RUNWY CNTRLINE	AIRCRAFT VELOCITY	PERCENT THRUST	FLAP ANGLE	EXHAUST VELOCITY	EXHAUST TEMPERATURE
8283.3	8283.3	650.7	0.0	141.8	100.0	-0.0	662.9	1171.1
8518.6	8518.6	694.1	0.0	141.8	100.0	-0.0	662.9	1171.1
8753.8	8753.8	738.7	0.0	141.8	100.0	-0.0	662.9	1171.1
8988.9	8988.9	783.7	0.0	141.8	100.0	-0.0	662.9	1171.1
9223.9	9223.9	828.8	0.0	141.8	100.0	-0.0	662.9	1171.1
9459.0	9459.0	873.9	0.0	141.8	100.0	-0.0	662.9	1171.1
9694.0	9694.1	919.0	0.0	141.8	100.0	-0.0	662.9	1171.1
9929.1	9929.1	964.0	0.0	141.8	100.0	-0.0	662.9	1171.1
10164.2	10164.2	1008.9	0.0	141.8	100.0	-0.0	662.9	1171.1
10399.3	10399.3	1053.8	0.0	141.8	100.0	-0.0	662.9	1171.1
10634.4	10634.4	1098.6	0.0	141.8	100.0	-0.0	662.9	1171.1
10869.5	10869.6	1143.3	0.0	141.8	100.0	-0.0	662.9	1171.1
11104.7	11104.7	1187.9	0.0	141.8	100.0	-0.0	662.9	1171.1
11339.8	11339.9	1232.5	0.0	141.8	100.0	-0.0	662.9	1171.1
11575.0	11575.0	1277.0	0.0	141.8	100.0	-0.0	662.9	1171.1
11810.2	11810.2	1321.4	0.0	141.8	100.0	-0.0	662.9	1171.1
12045.4	12045.4	1365.7	0.0	141.8	100.0	-0.0	662.9	1171.1
12280.6	12280.6	1409.9	0.0	141.8	100.0	-0.0	662.9	1171.1
12515.8	12515.9	1454.1	0.0	141.8	100.0	-0.0	662.9	1171.1
12751.1	12751.1	1498.2	0.0	141.8	100.0	-0.0	662.9	1171.1
12760.8	12760.9	1500.0	0.0	141.8	100.0	-0.0	662.9	1171.1
12878.4	12878.4	1521.8	0.0	141.6	85.0	-0.0	606.9	1124.3
12901.9	12901.9	1526.1	0.0	141.5	82.0	-0.0	595.3	1115.8
13137.1	13137.1	1565.7	0.0	141.0	82.0	-0.0	595.3	1115.8
13372.6	13372.7	1599.3	0.0	141.0	82.0	-0.0	595.3	1115.8
13608.7	13608.8	1628.7	0.0	141.0	82.0	-0.0	595.3	1115.8
13845.1	13845.1	1656.4	0.0	141.0	82.0	-0.0	595.3	1115.8
14081.5	14081.5	1683.4	0.0	141.0	82.0	-0.0	595.3	1115.8
14317.9	14317.9	1710.0	0.0	141.0	82.0	-0.0	595.3	1115.8
14554.4	14554.4	1736.5	0.0	141.0	82.0	-0.0	595.3	1115.8
14790.8	14790.9	1762.9	0.0	141.0	82.0	-0.0	595.3	1115.8
15027.3	15027.3	1789.2	0.0	141.0	82.0	-0.0	595.3	1115.8
15263.8	15263.8	1815.5	0.0	141.0	82.0	-0.0	595.3	1115.8
15500.3	15500.3	1841.8	0.0	141.0	82.0	-0.0	595.3	1115.8
15736.7	15736.8	1868.0	0.0	141.0	82.0	-0.0	595.3	1115.8
15973.2	15973.3	1894.1	0.0	141.0	82.0	-0.0	595.3	1115.8
16209.7	16209.8	1920.3	0.0	141.0	82.0	-0.0	595.3	1115.8
16446.2	16446.3	1946.4	0.0	141.0	82.0	-0.0	595.3	1115.8
16682.7	16682.8	1972.4	0.0	141.0	82.0	-0.0	595.3	1115.8
16919.2	16919.3	1998.4	0.0	141.0	82.0	-0.0	595.3	1115.8

TAKEOFF PARAMETERS

DISTANCE FBR ALONG FL PATH	DIST FBR ALONG RUNWY CNTRLINE	ALTITUDE	DISTANCE FROM RUNWY CNTRLINE	AIRCRAFT VELOCITY	PERCENT THRUST	FLAP ANGLE	EXHAUST VELOCITY	EXHAUST TEMPERATURE
17155.7	17155.8	2024.4	0.0	141.0	82.0	-0.0	595.3	1115.6
17392.2	17392.3	2050.4	0.0	141.0	82.0	-0.0	595.3	1115.8
17628.8	17628.8	2076.3	0.0	141.0	82.0	-0.0	595.3	1115.6
17865.3	17865.3	2102.1	0.0	141.0	82.0	-0.0	595.3	1115.8
18101.8	18101.8	2127.9	0.0	141.0	82.0	-0.0	595.3	1115.6
18338.3	18338.3	2153.7	0.0	141.0	82.0	-0.0	595.3	1115.6
18574.8	18574.9	2179.5	0.0	141.0	82.0	-0.0	595.3	1115.6
18811.4	18811.4	2205.2	0.0	141.0	82.0	-0.0	595.3	1115.8
19047.9	19047.9	2230.9	0.0	141.0	82.0	-0.0	595.3	1115.8
19284.4	19284.5	2256.5	0.0	141.0	82.0	-0.0	595.3	1115.8
19521.0	19521.0	2282.1	0.0	141.0	82.0	-0.0	595.3	1115.8
19757.5	19757.6	2307.7	0.0	141.0	82.0	-0.0	595.3	1115.8
19994.1	19994.1	2333.2	0.0	141.0	82.0	-0.0	595.3	1115.8
20230.6	20230.7	2358.7	0.0	141.0	82.0	-0.0	595.3	1115.8
20467.2	20467.2	2384.2	0.0	141.0	82.0	-0.0	595.3	1115.6
20703.7	20703.8	2409.6	0.0	141.0	82.0	-0.0	595.3	1115.8
20940.3	20940.3	2434.9	0.0	141.0	82.0	-0.0	595.3	1115.8
21176.9	21176.9	2460.3	0.0	141.0	82.0	-0.0	595.3	1115.6
21266.0	21266.0	2469.8	0.0	141.0	82.0	-0.0	595.3	1115.8
21502.5	21502.6	2495.1	0.0	141.0	82.0	-0.0	595.3	1115.8
21739.1	21739.1	2520.4	0.0	141.0	82.0	-0.0	595.3	1115.6
21975.7	21975.7	2545.6	0.0	141.0	82.0	-0.0	595.3	1115.6
22212.3	22212.3	2570.7	0.0	141.0	82.0	-0.0	595.3	1115.6
22448.8	22448.9	2595.9	0.0	141.0	82.0	-0.0	595.3	1115.8
22685.4	22685.5	2621.0	0.0	141.0	82.0	-0.0	595.3	1115.6
22922.0	22922.1	2646.0	0.0	141.0	82.0	-0.0	595.3	1115.6
23158.6	23158.6	2671.1	0.0	141.0	82.0	-0.0	595.3	1115.6
23395.2	23395.3	2696.1	0.0	141.0	82.0	-0.0	595.3	1115.6
23631.8	23631.9	2721.0	0.0	141.0	82.0	-0.0	595.3	1115.6
23868.4	23868.4	2745.9	0.0	141.0	82.0	-0.0	595.3	1115.8
24105.0	24105.1	2770.8	0.0	141.0	82.0	-0.0	595.3	1115.6
24341.6	24341.7	2795.6	0.0	141.0	82.0	-0.0	595.3	1115.6
24578.2	24578.3	2820.4	0.0	141.0	82.0	-0.0	595.3	1115.8
24814.9	24814.9	2845.2	0.0	141.0	82.0	-0.0	595.3	1115.8
35000.0	35000.0	3850.0	0.0	141.0	82.0	-0.0	595.3	1115.6

A P P R O A C H   P A R A M E T E R S

DISTANCE TT ALONG FL PATH	DIST TT ALONG RUNWY CNTRLINE	ALTITUDE	DISTANCE FROM RUNWY CNTRLINE	AIRCRAFT VELOCITY	PERCENT THRUST	FLAP ANGLE	EXHAUST VELOCITY	EXHAUST TEMPERATURE
0.0	0.0	35.0	0.0	95.1	64.5	39.2	524.0	1059.7
247.0	247.0	58.2	0.0	95.1	64.5	39.2	524.0	1059.7
566.7	566.7	88.3	0.0	95.2	64.4	39.2	523.5	1059.3
886.6	886.6	118.4	0.0	95.2	64.4	39.2	523.5	1059.3
1206.7	1206.7	148.5	0.0	95.3	64.5	39.2	524.0	1059.7
1527.0	1527.0	178.6	0.0	95.3	64.5	39.2	524.0	1059.7
1847.5	1847.5	208.8	0.0	95.4	64.3	39.2	523.1	1058.9
2168.3	2168.3	239.0	0.0	95.5	64.3	39.2	523.1	1058.9
2489.3	2489.3	269.2	0.0	95.6	64.1	39.2	522.3	1058.1
2810.8	2810.8	299.4	0.0	95.7	63.9	39.2	521.4	1057.3
3132.6	3132.6	329.7	0.0	95.8	63.5	39.2	519.6	1055.7
3455.0	3455.0	359.9	0.0	96.0	63.2	39.2	518.5	1054.5
3778.1	3778.1	390.1	0.0	96.2	62.9	39.2	517.3	1053.3
4101.9	4101.9	420.4	0.0	96.5	62.4	39.2	515.2	1051.3
4426.7	4426.7	451.0	0.0	96.6	61.3	39.2	510.6	1046.6
4752.6	4752.6	481.9	0.0	97.2	59.6	39.2	503.3	1039.6
5080.0	5080.0	512.8	0.0	97.7	57.8	39.2	494.8	1030.5
5409.2	5409.2	543.5	0.0	98.3	56.5	39.2	488.8	1024.0
5740.8	5740.8	573.8	0.0	99.0	55.7	39.2	485.0	1020.0
6075.3	6075.3	604.3	0.0	99.9	54.4	39.2	479.0	1013.5
6412.9	6412.9	635.7	0.0	101.0	51.3	39.2	464.6	997.9
6754.4	6754.4	668.7	0.0	102.3	45.6	39.2	438.3	969.4
7100.6	7100.6	702.7	0.0	103.9	36.6	39.2	404.9	938.2
7453.2	7453.2	736.4	0.0	106.0	33.4	39.2	370.0	923.1
7813.8	7813.8	768.6	0.0	108.6	31.5	39.2	357.8	917.8
8184.0	8184.0	800.3	0.0	111.5	30.8	39.2	353.3	915.8
8564.2	8564.2	835.1	0.0	114.7	30.9	39.2	353.9	916.1
8660.8	8660.8	844.9	0.0	115.4	30.9	39.2	353.9	916.1
8758.0	8758.0	855.1	0.0	116.1	30.9	39.2	353.9	916.1
8855.7	8855.7	865.8	0.0	116.7	30.9	39.2	353.9	916.1
8953.8	8953.8	876.5	0.0	117.3	30.9	39.2	353.9	916.1
9052.5	9052.5	887.0	0.0	117.9	30.9	39.2	353.9	916.1
9151.7	9151.7	896.9	0.0	118.4	30.9	39.2	353.9	916.1
9253.3	9253.3	906.6	0.0	118.7	30.9	37.6	353.9	916.1
9453.1	9453.1	925.7	0.0	119.2	30.9	34.4	353.9	916.1
9653.6	9653.6	944.5	0.0	119.5	30.9	31.2	353.9	916.1
9854.7	9854.7	962.9	0.0	119.8	30.9	28.0	353.9	916.1
10056.2	10056.2	981.3	0.0	120.0	30.9	24.8	353.9	916.1
10258.0	10258.0	1000.0	0.0	120.2	30.9	21.6	353.9	916.1
10617.8	10617.8	1034.1	0.0	120.3	30.6	21.6	352.0	915.3

A P P R O A C H P A R A M E T E R S

DISTANCE FT ALONG FL PATH	DIST FT ALONG RUNWY CNTRLINE	ALTITUDE	DISTANCE FROM RUNWY CNTRLINE	AIRCRAFT VELOCITY	PERCENT THRUST	FLAP ANGLE	EXHAUST VELOCITY	EXHAUST TEMPERATURE
11022.1	11022.1	1072.6	0.0	120.4	30.6	21.6	352.0	915.3
11426.7	11426.7	1111.0	0.0	120.4	30.6	21.6	352.0	915.3
11831.7	11831.7	1148.7	0.0	120.6	30.7	21.6	352.7	915.5
12237.2	12237.3	1185.9	0.0	120.8	30.7	21.6	352.7	915.5
12643.6	12643.6	1223.3	0.0	121.0	30.7	21.6	352.7	915.5
13050.6	13050.9	1261.6	0.0	121.4	27.9	21.6	334.6	907.7
13459.9	13459.9	1300.9	0.0	122.1	22.7	21.6	301.2	893.2
13872.1	13872.1	1340.6	0.0	123.3	17.9	21.6	270.4	879.9
14289.1	14289.1	1379.6	0.0	124.9	15.1	21.6	252.5	872.1
14712.0	14712.0	1418.5	0.0	126.8	15.1	21.6	252.5	872.1
15141.1	15141.1	1458.7	0.0	128.6	15.0	21.6	251.9	871.8
15576.2	15576.2	1499.9	0.0	130.3	15.0	21.6	251.9	871.8
16017.2	16017.2	1541.3	0.0	132.1	15.0	21.6	251.9	871.8
16464.1	16464.1	1583.0	0.0	133.8	15.0	21.6	251.9	871.8
16917.0	16917.0	1625.2	0.0	135.6	15.0	21.6	251.9	871.8
17375.8	17375.8	1668.4	0.0	137.4	15.0	21.6	251.9	871.8
17840.5	17840.5	1712.8	0.0	139.2	15.0	21.6	251.9	871.8
18311.0	18311.0	1757.9	0.0	140.9	15.0	21.6	251.9	871.8
18787.3	18787.4	1802.9	0.0	142.6	15.0	21.6	251.9	871.8
19269.9	19269.9	1847.4	0.0	144.5	15.0	21.6	251.9	871.8
19759.1	19759.1	1892.1	0.0	146.5	15.0	21.6	251.9	871.8
20254.9	20254.9	1938.3	0.0	148.5	15.0	21.6	251.9	871.8
20757.3	20757.3	1986.7	0.0	150.5	15.0	21.6	251.9	871.8
21266.1	21266.1	2036.5	0.0	152.4	15.0	21.6	251.9	871.8
21781.5	21781.5	2086.0	0.0	154.4	15.0	21.6	251.9	871.8
22304.1	22304.1	2134.0	0.0	156.6	15.0	21.6	251.9	871.8
22834.6	22834.6	2181.2	0.0	159.0	15.0	21.6	251.9	871.8
23373.5	23373.5	2230.2	0.0	161.6	15.0	21.6	251.9	871.8
23920.6	23920.6	2282.8	0.0	164.1	15.0	21.6	251.9	871.8
24475.6	24475.6	2338.5	0.0	166.4	15.0	21.6	251.9	871.8
25038.9	25038.9	2394.3	0.0	168.9	15.0	21.6	251.9	871.8
25611.5	25611.5	2447.0	0.0	171.8	15.0	21.6	251.9	871.8
26194.4	26194.4	2500.0	0.0	175.0	15.0	21.6	251.9	871.8

E P N L   G R I D – T A K E O F F

D I S T A N C E   F R O M   F L I G H T   P A T H   C E N T E R L I N E ,   F T

DISTANCE F.B.R.	0	500	1000	1500	2000	2500	3000	3500	4000	4500
	5000	5500	6000	6500	7000	7500	8000	8500	9000	9500
TYPE NOISE										
0.										
ENGINE NOISE	115.0	97.8	87.9	81.9	77.7	74.4				
FLAP NOISE	112.7	92.6	85.6	81.5	78.3	75.9				
TOTAL NOISE	117.0	98.9	89.9	84.7	81.0	78.2				
500.										
ENGINE NOISE	114.8	97.6	87.7	81.7	77.5	74.2				
FLAP NOISE	112.5	92.4	85.4	81.3	78.1	75.7				
TOTAL NOISE	116.8	98.7	89.7	84.5	80.8	78.0				
1000.										
ENGINE NOISE	111.8	94.6	84.7	78.7	74.5					
FLAP NOISE	109.5	89.4	82.4	78.2	75.1					
TOTAL NOISE	113.8	95.7	86.7	81.5	77.8					
1500.										
ENGINE NOISE	110.0	92.8	82.9	77.0						
FLAP NOISE	107.8	87.6	80.7	76.5						
TOTAL NOISE	112.1	94.0	85.0	79.8						
2000.										
ENGINE NOISE	109.4	93.6	83.8	77.8	73.6					
FLAP NOISE	107.0	88.5	81.6	77.4	74.2					
TOTAL NOISE	111.4	94.8	85.9	80.6	76.9					
2500.										
ENGINE NOISE	108.6	94.5	84.8	78.8	74.5					
FLAP NOISE	105.9	89.3	82.5	78.3	75.1					
TOTAL NOISE	110.5	95.7	86.8	81.6	77.8					
3000.										
ENGINE NOISE	107.2	95.2	85.7	79.7	75.5					
FLAP NOISE	103.9	90.2	83.4	79.3	76.1					
TOTAL NOISE	108.9	96.4	87.7	82.5	78.8					
3500.										
ENGINE NOISE	106.0	95.4	86.1	80.2	75.9					
FLAP NOISE	102.2	90.7	83.9	79.8	76.6					
TOTAL NOISE	107.5	96.7	88.1	83.0	79.3					

E P N L   G R I D - T A K E O F F

D I S T A N C E   F R O M   F L I G H T   P A T H   C E N T E R L I N E ,   F T

DISTANCE F.B.R. / TYPE NOISE	0 / 5000	500 / 5500	1000 / 6000	1500 / 6500	2000 / 7000	2500 / 7500	3000 / 8000	3500 / 8500	4000 / 9000	4500 / 9500
4000.										
ENGINE NOISE	104.8	95.6	86.4	80.5	76.3					
FLAP NOISE	100.6	91.1	84.3	80.2	76.9					
TOTAL NOISE	106.2	96.9	88.5	83.4	79.6					
4500.										
ENGINE NOISE	103.0	95.7	86.6	80.9	76.6					
FLAP NOISE	99.3	91.6	84.6	80.5	77.3					
TOTAL NOISE	104.6	97.1	88.8	83.7	80.0					
5000.										
ENGINE NOISE	101.5	95.5	86.9	81.1	76.9	73.4				
FLAP NOISE	98.1	91.8	85.0	80.9	77.6	75.1				
TOTAL NOISE	103.1	97.0	89.0	84.0	80.3	77.3				
5500.										
ENGINE NOISE	100.2	94.9	87.1	81.4	77.2	73.7				
FLAP NOISE	97.2	91.7	85.4	81.2	78.0	75.4				
TOTAL NOISE	101.9	96.6	89.3	84.3	80.6	77.6				
6000.										
ENGINE NOISE	99.0	94.3	87.3	81.6	77.4	73.9				
FLAP NOISE	95.5	90.8	84.9	80.7	77.4	74.6				
TOTAL NOISE	100.6	95.9	89.3	84.2	80.4	77.4				
6500.										
ENGINE NOISE	98.0	93.7	87.4	81.7	77.5					
FLAP NOISE	93.3	89.0	83.6	79.3	76.0					
TOTAL NOISE	99.3	95.0	88.9	83.7	79.8					
7000.										
ENGINE NOISE	97.2	93.2	87.4	81.6	77.4					
FLAP NOISE	91.2	87.1	82.1	77.7	74.4					
TOTAL NOISE	98.2	94.1	88.5	83.1	79.2					
7500.										
ENGINE NOISE	96.6	92.8	87.4	81.6	77.4					
FLAP NOISE	90.6	86.7	81.9	77.5	74.1					
TOTAL NOISE	97.6	93.7	88.5	83.0	79.1					

E P N L G R I D - T A K E O F F

D I S T A N C E F R O M F L I G H T P A T H C E N T E R L I N E , F T

DISTANCE F.B.R. / TYPE NOISE	0 5000	500 5500	1000 6000	1500 6500	2000 7000	2500 7500	3000 8000	3500 8500	4000 9000	4500 9500
8000.										
ENGINE NOISE	95.6	92.3	87.3	81.8	77.5					
FLAP NOISE	90.0	86.4	82.0	77.8	74.4					
TOTAL NOISE	96.6	93.3	88.5	83.2	79.3					
8500.										
ENGINE NOISE	94.1	91.4	87.0	82.1	77.8					
FLAP NOISE	89.3	86.1	81.9	78.3	74.8					
TOTAL NOISE	95.3	92.6	88.2	83.6	79.6					
9000.										
ENGINE NOISE	92.7	90.6	86.6	82.6	78.1					
FLAP NOISE	88.5	85.7	81.8	79.0	75.3					
TOTAL NOISE	94.1	91.6	87.9	84.2	79.9					
9500.										
ENGINE NOISE	91.5	89.7	86.2	82.9	78.5	74.9				
FLAP NOISE	87.6	85.3	81.7	79.5	75.7	72.9				
TOTAL NOISE	93.0	91.0	87.5	84.5	80.3	77.0				
10000.										
ENGINE NOISE	90.3	88.8	85.8	82.7	78.8	75.2				
FLAP NOISE	87.2	85.0	81.6	79.5	76.3	73.3				
TOTAL NOISE	92.0	90.3	87.2	84.4	80.8	77.3				
10500.										
ENGINE NOISE	89.3	88.0	85.3	82.4	79.2	75.5				
FLAP NOISE	86.5	84.5	81.4	79.4	76.8	73.7				
TOTAL NOISE	91.1	89.6	86.8	84.2	81.2	77.7				
11000.										
ENGINE NOISE	88.4	87.3	84.8	82.2	79.5	75.8				
FLAP NOISE	86.0	84.1	81.1	79.3	77.2	74.0				
TOTAL NOISE	90.3	89.0	86.4	84.0	81.5	78.0				
11500.										
ENGINE NOISE	87.5	86.5	84.4	81.9	79.3	76.1				
FLAP NOISE	85.4	83.7	80.9	79.2	77.2	74.5				
TOTAL NOISE	89.6	88.4	86.0	83.7	81.4	78.4				

E P N L G R I D - T A K E O F F

D I S T A N C E F R O M F L I G H T P A T H C E N T E R L I N E , F T

DISTANCE F.B.R. / TYPE NOISE	0 / 5000	500 / 5500	1000 / 6000	1500 / 6500	2000 / 7000	2500 / 7500	3000 / 8000	3500 / 8500	4000 / 9000	4500 / 9500
12000.										
ENGINE NOISE	86.7	85.9	83.9	81.6	79.1	76.5				
FLAP NOISE	84.9	83.3	80.7	79.1	77.1	74.9				
TOTAL NOISE	88.9	87.8	85.6	83.5	81.2	78.8				
12500.										
ENGINE NOISE	85.9	85.2	83.4	81.2	78.9	76.7				
FLAP NOISE	84.5	82.9	80.5	78.9	77.0	75.3				
TOTAL NOISE	88.3	87.2	85.2	83.2	81.0	79.0				
13000.										
ENGINE NOISE	85.2	84.6	83.0	80.9	78.6	76.5				
FLAP NOISE	84.0	82.6	80.2	78.8	76.9	75.2				
TOTAL NOISE	87.7	86.7	84.8	83.0	80.9	78.9				
13500.										
ENGINE NOISE	82.2	81.6	80.1	78.1						
FLAP NOISE	80.2	78.5	76.4	75.0						
TOTAL NOISE	84.3	83.3	81.7	79.8						
14000.										
ENGINE NOISE	81.8	81.2	79.9	77.8						
FLAP NOISE	80.0	78.3	76.2	74.9						
TOTAL NOISE	84.0	83.0	81.4	79.6						
14500.										
ENGINE NOISE	81.4	80.9	79.6	77.6						
FLAP NOISE	79.7	78.1	76.1	74.8						
TOTAL NOISE	83.7	82.7	81.2	79.5						
15000.										
ENGINE NOISE	81.0	80.6	79.3	77.4						
FLAP NOISE	79.5	77.9	76.0	74.7						
TOTAL NOISE	83.4	82.5	81.0	79.3						
15500.										
ENGINE NOISE	80.7	80.3	79.0	77.2						
FLAP NOISE	79.3	77.6	75.8	74.6						
TOTAL NOISE	83.1	82.2	80.7	79.1						

E P N L   G R I D - T A K E O F F

D I S T A N C E   F R O M   F L I G H T   P A T H   C E N T E R L I N E ,   F T

DISTANCE F.B.R. / TYPE NOISE	0 / 5000	500 / 5500	1000 / 6000	1500 / 6500	2000 / 7000	2500 / 7500	3000 / 8000	3500 / 8500	4000 / 9000	4500 / 9500
16000.										
ENGINE NOISE	80.4	80.0	78.7	77.0						
FLAP NOISE	79.1	77.6	75.7	74.6						
TOTAL NOISE	82.8	81.9	80.5	78.9						
16500.										
ENGINE NOISE	80.1	79.7	78.4	76.7						
FLAP NOISE	78.9	77.4	75.6	74.5						
TOTAL NOISE	82.5	81.7	80.2	78.8						
17000.										
ENGINE NOISE	79.8	79.3	78.1	76.5						
FLAP NOISE	78.7	77.2	75.5	74.4						
TOTAL NOISE	82.3	81.4	80.0	78.6						
17500.										
ENGINE NOISE	79.4	79.0	77.9							
FLAP NOISE	78.5	77.0	75.3							
TOTAL NOISE	82.0	81.1	79.8							
18000.										
ENGINE NOISE	79.1	76.7	77.6							
FLAP NOISE	78.3	76.9	75.2							
TOTAL NOISE	81.7	80.9	79.6							
18500.										
ENGINE NOISE	78.7	78.4	77.3							
FLAP NOISE	78.1	76.7	75.1							
TOTAL NOISE	81.4	80.6	79.3							
19000.										
ENGINE NOISE	78.4	78.1	77.1							
FLAP NOISE	77.9	76.5	74.9							
TOTAL NOISE	81.2	80.4	79.1							
19500.										
ENGINE NOISE	78.1	77.8	76.8							
FLAP NOISE	77.7	76.3	74.8							
TOTAL NOISE	80.9	80.1	78.9							

E P N L G R I D - T A K E O F F

D I S T A N C E F R O M F L I G H T P A T H C E N T E R L I N E , F T

DISTANCE F.B.R.	0	500	1000	1500	2000	2500	3000	3500	4000	4500
	5000	5500	6000	6500	7000	7500	8000	8500	9000	9500
TYPE NOISE										
20000.										
ENGINE NOISE	77.8	77.5								
FLAP NOISE	77.5	76.2								
TOTAL NOISE	80.7	79.9								
20500.										
ENGINE NOISE	77.5	77.2								
FLAP NOISE	77.3	76.0								
TOTAL NOISE	80.4	79.6								
21000.										
ENGINE NOISE	77.2	76.9								
FLAP NOISE	77.2	75.9								
TOTAL NOISE	80.2	79.4								
21500.										
ENGINE NOISE	76.9	76.6								
FLAP NOISE	77.0	75.7								
TOTAL NOISE	80.0	79.2								

E P N L   G R I D - A P P R O A C H

D I S T A N C E   F R O M   F L I G H T   P A T H   C E N T E R L I N E ,   F T

DISTANCE T.T. / TYPE NOISE	0 5000	500 5500	1000 6000	1500 6500	2000 7000	2500 7500	3000 8000	3500 8500	4000 9000	4500 9500
0.										
ENGINE NOISE	104.9	89.6	79.3	72.0						
FLAP NOISE	102.8	84.8	77.4	71.8						
TOTAL NOISE	107.0	90.9	81.5	74.9						
500.										
ENGINE NOISE	103.8	90.4	80.3	73.2						
FLAP NOISE	101.3	85.7	78.4	73.0						
TOTAL NOISE	105.8	91.7	82.5	76.1						
1000.										
ENGINE NOISE	102.7	90.9	81.0	74.0						
FLAP NOISE	99.8	86.3	79.1	73.8						
TOTAL NOISE	104.5	92.2	83.2	76.9						
1500.										
ENGINE NOISE	101.6	91.2	81.5	74.6						
FLAP NOISE	98.3	86.9	79.7	74.5						
TOTAL NOISE	103.3	92.5	83.7	77.6						
2000.										
ENGINE NOISE	100.2	91.3	81.8	75.1						
FLAP NOISE	96.9	87.4	80.1	75.0						
TOTAL NOISE	101.9	92.8	84.1	78.1						
2500.										
ENGINE NOISE	98.7	91.5	82.1	75.5						
FLAP NOISE	95.9	87.9	80.5	75.4						
TOTAL NOISE	100.5	93.1	84.4	78.5						
3000.										
ENGINE NOISE	97.4	91.2	82.3	75.8						
FLAP NOISE	94.9	88.0	80.8	75.8						
TOTAL NOISE	99.4	92.9	84.6	78.8						
3500.										
ENGINE NOISE	96.3	90.8	82.5	76.0						
FLAP NOISE	94.1	87.9	81.1	76.0						
TOTAL NOISE	98.3	92.6	84.8	79.0						

EPNL GRID - APPROACH

DISTANCE FROM FLIGHT PATH CENTERLINE, FT

DISTANCE T.T. / TYPE NOISE	0 5000	500 5500	1000 6000	1500 6500	2000 7000	2500 7500	3000 8000	3500 8500	4000 9000	4500 9500
4000.										
ENGINE NOISE	95.2	90.2	82.6	76.2						
FLAP NOISE	93.3	87.7	81.3	76.3						
TOTAL NOISE	97.4	92.2	85.0	79.2						
4500.										
ENGINE NOISE	94.1	89.5	82.6	76.2						
FLAP NOISE	92.4	87.3	81.3	76.2						
TOTAL NOISE	96.3	91.5	85.0	79.2						
5000.										
ENGINE NOISE	92.7	88.5	82.3	75.9						
FLAP NOISE	91.1	86.5	81.0	75.8						
TOTAL NOISE	95.0	90.6	84.7	78.8						
5500.										
ENGINE NOISE	91.2	87.5	82.1	75.6						
FLAP NOISE	89.8	85.5	80.7	75.4						
TOTAL NOISE	93.6	89.6	84.5	78.5						
6000.										
ENGINE NOISE	89.9	86.6	81.7	75.5						
FLAP NOISE	86.8	84.6	80.2	75.2						
TOTAL NOISE	92.4	88.8	84.0	78.4						
6500.										
ENGINE NOISE	88.1	85.2	80.6	74.8						
FLAP NOISE	86.9	83.1	78.7	74.1						
TOTAL NOISE	90.6	87.3	82.7	77.5						
7000.										
ENGINE NOISE	85.2	82.6	78.3	73.1						
FLAP NOISE	83.3	79.5	75.3	71.4						
TOTAL NOISE	87.4	84.3	80.1	75.3						
7500.										
ENGINE NOISE	81.5	79.1	75.1							
FLAP NOISE	79.2	75.3	71.4							
TOTAL NOISE	83.5	80.6	76.6							

E P N L   G R I D – A P P R O A C H

D I S T A N C E   F R O M   F L I G H T   P A T H   C E N T E R L I N E ,   F T

DISTANCE T.T. / TYPE NOISE	0 / 5000	500 / 5500	1000 / 6000	1500 / 6500	2000 / 7000	2500 / 7500	3000 / 8000	3500 / 8500	4000 / 9000	4500 / 9500
8000.										
ENGINE NOISE	79.7	77.6								
FLAP NOISE	77.5	73.7								
TOTAL NOISE	81.8	79.1								
8500.										
ENGINE NOISE	76.8	76.9								
FLAP NOISE	76.8	73.2								
TOTAL NOISE	80.9	78.4								
9000.										
ENGINE NOISE	78.1	76.3								
FLAP NOISE	76.3	72.9								
TOTAL NOISE	80.3	77.9								
9500.										
ENGINE NOISE	77.4	75.8								
FLAP NOISE	75.2	72.0								
TOTAL NOISE	79.4	77.3								

80.0 EPNDB NOISE CONTOUR POINTS - TAKEOFF

ALL DISTANCES IN FEET

DISTANCE FBR ALONG FL PATH	DISTANCE FROM FL PATH CENTERLINE	COORDINATE POINTS	COORDINATE POINTS
0.	2184.	(0., 2184.)	(0., -2184.)
500.	2147.	(500., 2147.)	(500., -2147.)
1000.	1703.	(1000., 1703.)	(1000., -1703.)
1500.	1477.	(1500., 1477.)	(1500., -1477.)
2000.	1584.	(2000., 1584.)	(2000., -1584.)
2500.	1712.	(2500., 1712.)	(2500., -1712.)
3000.	1837.	(3000., 1837.)	(3000., -1837.)
3500.	1901.	(3500., 1901.)	(3500., -1901.)
4000.	1951.	(4000., 1951.)	(4000., -1951.)
4500.	1997.	(4500., 1997.)	(4500., -1997.)
5000.	2051.	(5000., 2051.)	(5000., -2051.)
5500.	2103.	(5500., 2103.)	(5500., -2103.)
6000.	2073.	(6000., 2073.)	(6000., -2073.)
6500.	1977.	(6500., 1977.)	(6500., -1977.)
7000.	1696.	(7000., 1696.)	(7000., -1696.)
7500.	1681.	(7500., 1681.)	(7500., -1681.)
8000.	1907.	(8000., 1907.)	(8000., -1907.)
8500.	1949.	(8500., 1949.)	(8500., -1949.)
9000.	1994.	(9000., 1994.)	(9000., -1994.)
9500.	2050.	(9500., 2050.)	(9500., -2050.)
10000.	2111.	(10000., 2111.)	(10000., -2111.)
10500.	2172.	(10500., 2172.)	(10500., -2172.)
11000.	2215.	(11000., 2215.)	(11000., -2215.)
11500.	2228.	(11500., 2228.)	(11500., -2228.)
12000.	2248.	(12000., 2248.)	(12000., -2248.)
12500.	2259.	(12500., 2259.)	(12500., -2259.)
13000.	2223.	(13000., 2223.)	(13000., -2223.)
13500.	1454.	(13500., 1454.)	(13500., -1454.)
14000.	1397.	(14000., 1397.)	(14000., -1397.)
14500.	1343.	(14500., 1343.)	(14500., -1343.)
15000.	1285.	(15000., 1285.)	(15000., -1285.)
15500.	1222.	(15500., 1222.)	(15500., -1222.)
16000.	1154.	(16000., 1154.)	(16000., -1154.)
16500.	1083.	(16500., 1083.)	(16500., -1083.)
17000.	1008.	(17000., 1008.)	(17000., -1008.)
17500.	923.	(17500., 923.)	(17500., -923.)
18000.	835.	(18000., 835.)	(18000., -835.)
18500.	743.	(18500., 743.)	(18500., -743.)
19000.	647.	(19000., 647.)	(19000., -647.)
19500.	548.	(19500., 548.)	(19500., -548.)

80.0 EPNDB NOISE CONTOUR POINTS - TAKEOFF

ALL DISTANCES IN FEET

DISTANCE FBR ALONG FL PATH	DISTANCE FROM FL PATH CENTERLINE	COORDINATE POINTS	COORDINATE POINTS
20000.	422.	(20000., 422.)	(20000., -422.)
20500.	272.	(20500., 272.)	(20500., -272.)
21000.	124.	(21000., 124.)	(21000., -124.)
21418.	0.	(21419., 0.)	(21419., 0.)

AREA WITHIN TAKEOFF CONTOUR = 2.41 SQUARE MILES
6.23 SQUARE KILOMETERS

60.0 EPNDB NOISE CONTOUR POINTS - APPROACH

ALL DISTANCES IN FEET

DISTANCE TT ALONG FL PATH	DISTANCE FROM FL PATH CENTERLINE	COORDINATE POINTS	COORDINATE POINTS
0.	2184.	(0., 2184.)	(0., -2184.)
500.	2063.	(500., 2063.)	(500., -2063.)
1000.	1530.	(1000., 1530.)	(1000., -1530.)
1500.	1302.	(1500., 1302.)	(1500., -1302.)
2000.	1339.	(2000., 1339.)	(2000., -1339.)
2500.	1371.	(2500., 1371.)	(2500., -1371.)
3000.	1396.	(3000., 1396.)	(3000., -1396.)
3500.	1416.	(3500., 1416.)	(3500., -1416.)
4000.	1434.	(4000., 1434.)	(4000., -1434.)
4500.	1432.	(4500., 1432.)	(4500., -1432.)
5000.	1402.	(5000., 1402.)	(5000., -1402.)
5500.	1376.	(5500., 1376.)	(5500., -1376.)
6000.	1356.	(6000., 1356.)	(6000., -1356.)
6500.	1261.	(6500., 1261.)	(6500., -1261.)
7000.	1007.	(7000., 1007.)	(7000., -1007.)
7500.	580.	(7500., 580.)	(7500., -580.)
8000.	331.	(8000., 331.)	(8000., -331.)
8500.	187.	(8500., 187.)	(8500., -187.)
9000.	60.	(9000., 60.)	(9000., -60.)
9167.	0.	(9167., 0.)	(9167., 0.)

AREA WITHIN APPROACH CONTOUR = 0.79 SQUARE MILES
2.04 SQUARE KILOMETERS

TOTAL AREA WITHIN CONTOUR = 3.19 SQUARE MILES
8.27 SQUARE KILOMETERS

65.0 EPNDB NOISE CONTOUR POINTS - TAKEOFF

ALL DISTANCES IN FEET

DISTANCE FBR ALONG FL PATH	DISTANCE FROM FL PATH CENTERLINE	COORDINATE POINTS	COORDINATE POINTS
0.	1472.	(0., 1472.)	(0., -1472.)
500.	1453.	(500., 1453.)	(500., -1453.)
1000.	1164.	(1000., 1164.)	(1000., -1164.)
1500.	999.	(1500., 999.)	(1500., -999.)
2000.	1082.	(2000., 1082.)	(2000., -1082.)
2500.	1173.	(2500., 1173.)	(2500., -1173.)
3000.	1260.	(3000., 1260.)	(3000., -1260.)
3500.	1305.	(3500., 1305.)	(3500., -1305.)
4000.	1340.	(4000., 1340.)	(4000., -1340.)
4500.	1371.	(4500., 1371.)	(4500., -1371.)
5000.	1402.	(5000., 1402.)	(5000., -1402.)
5500.	1432.	(5500., 1432.)	(5500., -1432.)
6000.	1422.	(6000., 1422.)	(6000., -1422.)
6500.	1375.	(6500., 1375.)	(6500., -1375.)
7000.	1326.	(7000., 1326.)	(7000., -1326.)
7500.	1318.	(7500., 1318.)	(7500., -1318.)
8000.	1331.	(8000., 1331.)	(8000., -1331.)
8500.	1351.	(8500., 1351.)	(8500., -1351.)
9000.	1387.	(9000., 1387.)	(9000., -1387.)
9500.	1422.	(9500., 1422.)	(9500., -1422.)
10000.	1388.	(10000., 1388.)	(10000., -1388.)
10500.	1343.	(10500., 1343.)	(10500., -1343.)
11000.	1286.	(11000., 1286.)	(11000., -1286.)
11500.	1219.	(11500., 1219.)	(11500., -1219.)
12000.	1141.	(12000., 1141.)	(12000., -1141.)
12500.	1053.	(12500., 1053.)	(12500., -1053.)
13000.	956.	(13000., 956.)	(13000., -956.)
13399.	0.	(13399., 0.)	(13399., 0.)

AREA WITHIN TAKEOFF CONTOUR = 1.22 SQUARE MILES
3.15 SQUARE KILOMETERS

85.0 EPNDB NOISE CONTOUR POINTS - APPROACH

ALL DISTANCES IN FEET

DISTANCE TT ALONG FL PATH	DISTANCE FROM FL PATH CENTERLINE	COORDINATE POINTS	COORDINATE POINTS
0.	1472.	(0., 1472.)	(0., -1472.)
500.	1276.	(500., 1276.)	(500., -1276.)
1000.	899.	(1000., 899.)	(1000., -899.)
1500.	927.	(1500., 927.)	(1500., -927.)
2000.	947.	(2000., 947.)	(2000., -947.)
2500.	966.	(2500., 966.)	(2500., -966.)
3000.	979.	(3000., 979.)	(3000., -979.)
3500.	990.	(3500., 990.)	(3500., -990.)
4000.	1002.	(4000., 1002.)	(4000., -1002.)
4500.	1002.	(4500., 1002.)	(4500., -1002.)
5000.	976.	(5000., 976.)	(5000., -976.)
5500.	949.	(5500., 949.)	(5500., -949.)
6000.	896.	(6000., 698.)	(6000., -698.)
6500.	749.	(6500., 749.)	(6500., -749.)
7000.	391.	(7000., 391.)	(7000., -391.)
7306.	0.	(7306., 0.)	(7306., 0.)

AREA WITHIN APPROACH CONTOUR = 0.49 SQUARE MILES
1.27 SQUARE KILOMETERS

TOTAL AREA WITHIN CONTOUR = 1.71 SQUARE MILES
4.43 SQUARE KILOMETERS

90.0 EPNDB NOISE CONTOUR POINTS - TAKEOFF

ALL DISTANCES IN FEET

DISTANCE FOR ALONG FL PATH	DISTANCE FROM FL PATH CENTERLINE	COORDINATE POINTS	COORDINATE POINTS
0.	996.	(0., 996.)	(0., -996.)
500.	985.	(500., 985.)	(500., -985.)
1000.	817.	(1000., 817.)	(1000., -817.)
1500.	721.	(1500., 721.)	(1500., -721.)
2000.	768.	(2000., 768.)	(2000., -768.)
2500.	819.	(2500., 819.)	(2500., -819.)
3000.	868.	(3000., 868.)	(3000., -868.)
3500.	891.	(3500., 891.)	(3500., -891.)
4000.	909.	(4000., 909.)	(4000., -909.)
4500.	926.	(4500., 926.)	(4500., -926.)
5000.	940.	(5000., 940.)	(5000., -940.)
5500.	954.	(5500., 954.)	(5500., -954.)
6000.	947.	(6000., 947.)	(6000., -947.)
6500.	912.	(6500., 912.)	(6500., -912.)
7000.	869.	(7000., 869.)	(7000., -869.)
7500.	855.	(7500., 855.)	(7500., -855.)
8000.	840.	(8000., 840.)	(8000., -840.)
8500.	793.	(8500., 793.)	(8500., -793.)
9000.	728.	(9000., 728.)	(9000., -728.)
9500.	647.	(9500., 647.)	(9500., -647.)
10000.	551.	(10000., 551.)	(10000., -551.)
10500.	379.	(10500., 379.)	(10500., -379.)
11000.	122.	(11000., 122.)	(11000., -122.)
11221.	0.	(11221., 0.)	(11221., 0.)

AREA WITHIN TAKEOFF CONTOUR = 0.64 SQUARE MILES
1.65 SQUARE KILOMETERS

90.0 EPNDB NOISE CONTOUR POINTS - APPROACH

ALL DISTANCES IN FEET

DISTANCE TT ALONG FL PATH	DISTANCE FROM FL PATH CENTERLINE	COORDINATE POINTS	COORDINATE POINTS
0.	996.	(0., 996.)	(0., -996.)
500.	592.	(500., 592.)	(500., -592.)
1000.	622.	(1000., 622.)	(1000., -622.)
1500.	644.	(1500., 644.)	(1500., -644.)
2000.	661.	(2000., 661.)	(2000., -661.)
2500.	678.	(2500., 678.)	(2500., -678.)
3000.	676.	(3000., 676.)	(3000., -676.)
3500.	666.	(3500., 666.)	(3500., -666.)
4000.	651.	(4000., 651.)	(4000., -651.)
4500.	618.	(4500., 618.)	(4500., -618.)
5000.	550.	(5000., 550.)	(5000., -550.)
5500.	452.	(5500., 452.)	(5500., -452.)
6000.	335.	(6000., 335.)	(6000., -335.)
6500.	87.	(6500., 87.)	(6500., -87.)
6590.	0.	(6590., 0.)	(6590., 0.)

AREA WITHIN APPROACH CONTOUR = 0.28 SQUARE MILES
0.73 SQUARE KILOMETERS

TOTAL AREA WITHIN CONTOUR = 0.92 SQUARE MILES
2.38 SQUARE KILOMETERS

95.0 EPNDB NOISE CONTOUR POINTS - TAKEOFF

ALL DISTANCES IN FEET

DISTANCE FBR ALONG FL PATH	DISTANCE FROM FL PATH CENTERLINE	COORDINATE POINTS	COORDINATE POINTS
0.	718.	(0., 718.)	(0., -718.)
500.	707.	(500., 707.)	(500., -707.)
1000.	539.	(1000., 539.)	(1000., -539.)
1500.	471.	(1500., 471.)	(1500., -471.)
2000.	494.	(2000., 494.)	(2000., -494.)
2500.	537.	(2500., 537.)	(2500., -537.)
3000.	580.	(3000., 580.)	(3000., -580.)
3500.	599.	(3500., 599.)	(3500., -599.)
4000.	612.	(4000., 612.)	(4000., -612.)
4500.	626.	(4500., 626.)	(4500., -626.)
5000.	628.	(5000., 628.)	(5000., -628.)
5500.	613.	(5500., 613.)	(5500., -613.)
6000.	569.	(6000., 569.)	(6000., -569.)
6500.	494.	(6500., 494.)	(6500., -494.)
7000.	393.	(7000., 393.)	(7000., -393.)
7500.	337.	(7500., 337.)	(7500., -337.)
8000.	243.	(8000., 243.)	(8000., -243.)
8500.	62.	(8500., 62.)	(8500., -62.)
8641.	0.	(8641., 0.)	(8641., 0.)

AREA WITHIN TAKEOFF CONTOUR = 0.32 SQUARE MILES
0.84 SQUARE KILOMETERS

95.0 EPNDB NOISE CONTOUR POINTS - APPROACH

ALL DISTANCES IN FEET

DISTANCE TT ALONG FL PATH	DISTANCE FROM FL PATH CENTERLINE	COORDINATE POINTS	COORDINATE POINTS
0.	718.	(0., 718.)	(0., -718.)
500.	383.	(500., 383.)	(500., -383.)
1000.	386.	(1000., 386.)	(1000., -386.)
1500.	386.	(1500., 386.)	(1500., -386.)
2000.	379.	(2000., 379.)	(2000., -379.)
2500.	372.	(2500., 372.)	(2500., -372.)
3000.	338.	(3000., 338.)	(3000., -338.)
3500.	288.	(3500., 288.)	(3500., -288.)
4000.	228.	(4000., 228.)	(4000., -228.)
4500.	138.	(4500., 138.)	(4500., -138.)
5000.	0.	(5000., 0.)	(5000., -0.)
5000.	0.	(5000., 0.)	(5000., 0.)

AREA WITHIN APPROACH CONTOUR = 0.12 SQUARE MILES
0.30 SQUARE KILOMETERS

TOTAL AREA WITHIN CONTOUR = 0.44 SQUARE MILES
1.14 SQUARE KILOMETERS

100.0 EPNDB NOISE CONTOUR POINTS - TAKEOFF

ALL DISTANCES IN FEET

DISTANCE FOR ALONG FL PATH	DISTANCE FROM FL PATH CENTERLINE	COORDINATE POINTS	COORDINATE POINTS
0.	470.	(0., 470.)	(0., -470.)
500.	465.	(500., 465.)	(500., -465.)
1000.	381.	(1000., 381.)	(1000., -381.)
1500.	333.	(1500., 333.)	(1500., -333.)
2000.	343.	(2000., 343.)	(2000., -343.)
2500.	353.	(2500., 353.)	(2500., -353.)
3000.	356.	(3000., 356.)	(3000., -356.)
3500.	348.	(3500., 348.)	(3500., -348.)
4000.	333.	(4000., 333.)	(4000., -333.)
4500.	306.	(4500., 306.)	(4500., -306.)
5000.	258.	(5000., 258.)	(5000., -258.)
5500.	182.	(5500., 182.)	(5500., -182.)
6000.	63.	(6000., 63.)	(6000., -63.)
6223.	0.	(6223., 0.)	(6223., 0.)

AREA WITHIN TAKEOFF CONTOUR = 0.14 SQUARE MILES
0.37 SQUARE KILOMETERS

100.0 EPNDB NOISE CONTOUR POINTS - APPROACH

ALL DISTANCES IN FEET

DISTANCE TT ALONG FL PATH	DISTANCE FROM FL PATH CENTERLINE	COORDINATE POINTS	COORDINATE POINTS
0.	470.	(0., 470.)	(0., -470.)
500.	205.	(500., 205.)	(500., -205.)
1000.	183.	(1000., 183.)	(1000., -183.)
1500.	153.	(1500., 153.)	(1500., -153.)
2000.	104.	(2000., 104.)	(2000., -104.)
2500.	36.	(2500., 36.)	(2500., -36.)
2729.	0.	(2729., 0.)	(2729., 0.)

AREA WITHIN APPROACH CONTOUR = 0.03 SQUARE MILES
0.09 SQUARE KILOMETERS

TOTAL AREA WITHIN CONTOUR = 0.18 SQUARE MILES
0.45 SQUARE KILOMETERS

C O M M U N I T Y   N O I S E   I M P A C T

AIRPORT -- SNA - ORANGE CO. (SANTA ANA)

RUNWAY -- 19R
RUNWAY COORDINATES -- (700.,   1800.) FEET RELATIVE TO AIRPORT REFERENCE POINT
RUNWAY ANGLE -- 241.2 DEGREES MEASURED COUNTERCLOCKWISE FROM EAST-WEST LINE

COORDS REL TO AIRPORT REF PT	COORDS REL TO RUNWAY BR PT	POPULATION	EPNL	ANNOYANCE FACTOR	NOISE IMPACT
(-9500., -16500.)	(20950., -122.)	36.5	80.0	0.001	0.02
(-9000., -16000.)	(20271., 75.)	36.5	80.4	0.006	0.31
(-9000., -15500.)	(19833., -166.)	36.5	80.5	0.010	0.36
(-9000., -15000.)	(19395., -407.)	36.5	80.3	0.006	0.23
(-9000., -14500.)	(18957., -647.)	36.5	80.0	0.000	0.01
(-8500., -15500.)	(19592., 272.)	36.5	80.4	0.009	0.32
(-8500., -15000.)	(19154., 32.)	36.5	81.0	0.021	0.76
(-8500., -14500.)	(18716., -209.)	36.5	81.0	0.020	0.72
(-8500., -14000.)	(18278., -450.)	36.5	80.8	0.016	0.59
(-6500., -13500.)	(17840., -691.)	36.5	80.5	0.009	0.33
(-8500., -13000.)	(17401., -932.)	36.5	80.0	0.000	0.02
(-8000., -15000.)	(18913., 470.)	36.5	80.5	0.009	0.33
(-8000., -14500.)	(18475., 229.)	36.5	81.1	0.021	0.79
(-8000., -14000.)	(18037., -12.)	36.5	81.7	0.033	1.22
(-8000., -13500.)	(17599., -253.)	36.5	81.5	0.030	1.10
(-8000., -13000.)	(17161., -494.)	36.5	81.3	0.027	0.98
(-8000., -12500.)	(16722., -735.)	36.5	80.9	0.018	0.66
(-8000., -12000.)	(16284., -976.)	36.5	80.4	0.008	0.31
(-7500., -14500.)	(18234., 667.)	36.5	80.3	0.006	0.24
(-7500., -14000.)	(17796., 426.)	36.5	81.1	0.022	0.81
(-7500., -13500.)	(17358., 185.)	36.5	81.6	0.035	1.29
(-7500., -13000.)	(16920., -56.)	36.5	82.2	0.045	1.63
(-7500., -12500.)	(16482., -297.)	36.5	82.0	0.041	1.50
(-7500., -12000.)	(16043., -537.)	36.5	81.6	0.036	1.33
(-7500., -11500.)	(15605., -778.)	36.5	81.3	0.026	0.97
(-7500., -11000.)	(15167., -1019.)	36.5	80.8	0.016	0.60
(-7500., -10500.)	(14729., -1260.)	36.5	80.2	0.004	0.14
(-7500., -8500.)	(12976., -2224.)	80.9	80.0	0.000	0.01
(-7000., -14000.)	(17555., 864.)	36.5	80.1	0.003	0.10
(-7000., -13500.)	(17117., 623.)	36.5	81.0	0.020	0.74
(-7000., -13000.)	(16679., 382.)	36.5	81.8	0.036	1.31
(-7000., -12500.)	(16241., 142.)	0.0	82.4	0.049	0.0
(-7000., -12000.)	(15803., -99.)	0.0	82.7	0.055	0.0
(-7000., -11500.)	(15364., -340.)	0.0	82.6	0.051	0.0
(-7000., -11000.)	(14926., -581.)	36.5	82.3	0.045	1.65
(-7000., -10500.)	(14488., -822.)	36.5	81.8	0.035	1.28
(-7000., -10000.)	(14050., -1063.)	36.5	81.2	0.023	0.86
(-7000., -9500.)	(13612., -1304.)	36.5	80.5	0.010	0.37

C O M M U N I T Y   N O I S E   I M P A C T

AIRPORT -- SNA - ORANGE CO. (SANTA ANA)

RUNWAY -- 19R
RUNWAY COORDINATES --. (700., 1800.) FEET RELATIVE TO AIRPORT REFERENCE POINT
RUNWAY ANGLE -- 241.2 DEGREES MEASURED COUNTERCLOCKWISE FROM EAST-WEST LINE

COORDS REL TO AIRPORT REF PT	COORDS REL TO RUNWAY BR PT	POPULATION	EPNL	ANNOYANCE FACTOR	NOISE IMPACT
(-7000., -8500.)	(12735., -1785.)	80.9	81.9	0.038	3.05
(-7000., -8000.)	(12297., -2026.)	80.9	81.0	0.020	1.61
(-6500., -13000.)	(16436., 821.)	0.0	80.8	0.016	0.0
(-6500., -12500.)	(16000., 580.)	0.0	81.7	0.034	0.0
(-6500., -12000.)	(15562., 339.)	0.0	82.5	0.049	0.0
(-6500., -11500.)	(15124., 98.)	0.0	83.1	0.062	0.0
(-6500., -11000.)	(14685., -143.)	0.0	83.3	0.066	0.0
(-6500., -10500.)	(14247., -384.)	0.0	83.1	0.062	0.0
(-6500., -10000.)	(13809., -625.)	36.5	82.7	0.055	2.00
(-6500., -9500.)	(13371., -866.)	36.5	82.9	0.059	2.15
(-6500., -9000.)	(12933., -1106.)	36.5	84.5	0.090	3.26
(-6500., -8500.)	(12495., -1347.)	36.5	83.8	0.077	2.81
(-6500., -8000.)	(12056., -1588.)	80.9	83.1	0.062	4.96
(-6500., -7500.)	(11618., -1829.)	80.9	82.1	0.043	3.46
(-6500., -7000.)	(11180., -2070.)	80.9	81.0	0.020	1.61
(-6000., -12500.)	(15759., 1018.)	0.0	80.5	0.011	0.0
(-6000., -12000.)	(15321., 777.)	0.0	81.5	0.029	0.0
(-6000., -11500.)	(14883., 536.)	0.0	82.4	0.048	0.0
(-6000., -11000.)	(14444., 295.)	0.0	83.1	0.063	0.0
(-6000., -10500.)	(14006., 54.)	0.0	83.9	0.077	0.0
(-6000., -10000.)	(13568., -186.)	0.0	85.9	0.078	0.0
(-6000., -9500.)	(13130., -427.)	0.0	86.0	0.119	0.0
(-6000., -9000.)	(12692., -668.)	36.5	86.4	0.127	4.65
(-6000., -8500.)	(12254., -909.)	36.5	85.8	0.116	4.22
(-6000., -8000.)	(11816., -1150.)	36.5	85.1	0.102	3.72
(-6000., -7500.)	(11377., -1391.)	80.9	84.3	0.086	6.96
(-6000., -7000.)	(10939., -1632.)	80.9	83.3	0.067	5.40
(-6000., -6500.)	(10501., -1873.)	80.9	82.0	0.040	3.20
(-6000., -6000.)	(10063., -2114.)	80.9	80.0	0.001	0.06
(-5500., -12000.)	(15080., 1215.)	0.0	80.2	0.004	0.0
(-5500., -11500.)	(14642., 974.)	0.0	81.2	0.024	0.0
(-5500., -11000.)	(14204., 733.)	0.0	82.2	0.043	0.0
(-5500., -10500.)	(13765., 493.)	0.0	83.2	0.064	0.0
(-5500., -10000.)	(13327., 252.)	0.0	85.0	0.100	0.0
(-5500., -9500.)	(12889., 11.)	0.0	87.8	0.156	0.0
(-5500., -9000.)	(12451., -230.)	0.0	87.8	0.157	0.0
(-5500., -8500.)	(12013., -471.)	36.5	87.6	0.156	5.72
(-5500., -8000.)	(11575., -712.)	36.5	87.3	0.145	5.32

C O M M U N I T Y   N O I S E   I M P A C T

AIRPORT -- SNA - ORANGE CO. (SANTA ANA)

RUNWAY -- 19R
RUNWAY COORDINATES -- (700., 1800.) FEET RELATIVE TO AIRPORT REFERENCE POINT
RUNWAY ANGLE -- 241.2 DEGREES MEASURED COUNTERCLOCKWISE FROM EAST-WEST LINE

COORDS REL TO AIRPORT REF PT	COORDS REL TO RUNWAY BR PT	POPULATION	EPNL	ANNOYANCE FACTOR	NOISE IMPACT
(-5500., -7500.)	(11137., -953.)	36.5	86.5	0.130	4.75
(-5500., -7000.)	(10698., -1194.)	80.9	85.6	0.113	9.13
(-5500., -6500.)	(10260., -1434.)	80.9	84.6	0.093	7.49
(-5500., -6000.)	(9822., -1675.)	31.6	83.1	0.062	1.95
(-5500., -5500.)	(9384., -1916.)	31.6	80.9	0.019	0.60
(-5000., -11000.)	(13963., 1172.)	0.0	80.6	0.016	0.0
(-5000., -10500.)	(13525., 931.)	0.0	81.9	0.038	0.0
(-5000., -10000.)	(13086., 690.)	0.0	85.4	0.109	0.0
(-5000., -9500.)	(12648., 449.)	0.0	87.2	0.143	0.0
(-5000., -9000.)	(12210., 208.)	0.0	88.2	0.164	0.0
(-5000., -8500.)	(11772., -33.)	0.0	89.1	0.183	0.0
(-5000., -8000.)	(11334., -274.)	0.0	89.1	0.183	0.0
(-5000., -7500.)	(10896., -515.)	0.0	89.0	0.181	0.0
(-5000., -7000.)	(10457., -755.)	0.0	88.2	0.164	0.0
(-5000., -6500.)	(10019., -996.)	0.0	87.2	0.143	0.0
(-5000., -6000.)	(9581., -1237.)	0.0	86.1	0.121	0.0
(-5000., -5500.)	(9143., -1478.)	0.0	84.4	0.088	0.0
(-5000., -5000.)	(8705., -1719.)	0.0	82.0	0.041	0.0
(-4500., -10500.)	(13284., 1369.)	25.9	81.7	0.033	0.87
(-4500., -10000.)	(12846., 1128.)	25.9	84.5	0.089	2.31
(-4500., -9500.)	(12407., 887.)	25.9	85.7	0.115	2.98
(-4500., -9000.)	(11969., 646.)	25.9	87.2	0.143	3.71
(-4500., -8500.)	(11531., 405.)	25.9	88.5	0.171	4.43
(-4500., -8000.)	(11093., 164.)	25.9	89.8	0.195	5.06
(-4500., -7500.)	(10655., -76.)	25.9	90.7	0.213	5.53
(-4500., -7000.)	(10217., -317.)	25.9	90.6	0.212	5.50
(-4500., -6500.)	(9778., -558.)	25.9	90.3	0.205	5.31
(-4500., -6000.)	(9340., -799.)	25.9	89.1	0.182	4.72
(-4500., -5500.)	(8902., -1040.)	25.9	87.6	0.153	3.95
(-4500., -5000.)	(8464., -1281.)	25.9	85.6	0.113	2.92
(-4500., -4500.)	(8026., -1522.)	25.9	83.1	0.062	1.60
(-4500., -4000.)	(7588., -1763.)	25.9	81.0	0.019	0.50
(-4000., -10000.)	(12605., 1566.)	0.0	82.9	0.056	0.0
(-4000., -9500.)	(12166., 1325.)	0.0	84.1	0.083	0.0
(-4000., -9000.)	(11728., 1084.)	0.0	85.4	0.109	0.0
(-4000., -8500.)	(11290., 843.)	36.5	86.9	0.138	5.06
(-4000., -8000.)	(10852., 603.)	36.5	88.6	0.172	6.30
(-4000., -7500.)	(10414., 362.)	36.5	90.2	0.204	7.44

C O M M U N I T Y   N O I S E   I M P A C T

AIRPORT -- SNA - ORANGE CO. (SANTA ANA)

RUNWAY -- 19R
RUNWAY COORDINATES -- (700.,   1800.) FEET RELATIVE TO AIRPORT REFERENCE POINT
RUNWAY ANGLE --   241.2 DEGREES MEASURED COUNTERCLOCKWISE FROM EAST-WEST LINE

COORDS REL TO AIRPORT REF PT	COORDS REL TO RUNWAY BR PT	POPULATION	EPNL	ANNOYANCE FACTOR	NOISE IMPACT
(-4000., -7000.)	(9976., 121.)	36.5	91.7	0.233	8.53
(-4000., -6500.)	(9538., -120.)	36.5	92.5	0.249	9.11
(-4000., -6000.)	(9099., -361.)	31.6	92.3	0.245	7.75
(-4000., -5500.)	(8661., -602.)	31.6	91.4	0.229	7.23
(-4000., -5000.)	(8223., -843.)	31.6	89.8	0.196	6.19
(-4000., -4500.)	(7785., -1084.)	31.6	87.6	0.151	4.79
(-4000., -4000.)	(7347., -1324.)	31.6	85.0	0.099	3.13
(-4000., -3500.)	(6909., -1565.)	31.6	82.7	0.054	1.71
(-4000., -3000.)	(6471., -1806.)	0.3	81.4	0.027	0.01
(-3500., -10000.)	(12364., 2004.)	0.0	81.1	0.021	0.0
(-3500., -9500.)	(11926., 1763.)	0.0	82.3	0.047	0.0
(-3500., -9000.)	(11487., 1523.)	36.5	83.6	0.073	2.67
(-3500., -8500.)	(11049., 1282.)	36.5	85.0	0.100	3.65
(-3500., -8000.)	(10611., 1041.)	36.5	86.5	0.129	4.73
(-3500., -7500.)	(10173., 800.)	36.5	88.2	0.165	6.03
(-3500., -7000.)	(9735., 559.)	36.5	90.3	0.206	7.53
(-3500., -6500.)	(9297., 318.)	31.6	92.1	0.242	7.65
(-3500., -6000.)	(8859., 77.)	31.6	94.1	0.282	8.90
(-3500., -5500.)	(8420., -164.)	31.6	94.6	0.292	9.23
(-3500., -5000.)	(7982., -405.)	31.6	93.9	0.279	8.80
(-3500., -4500.)	(7544., -645.)	31.6	92.2	0.244	7.70
(-3500., -4000.)	(7106., -886.)	31.6	89.8	0.196	6.18
(-3500., -3500.)	(6668., -1127.)	31.6	87.5	0.149	4.71
(-3500., -3000.)	(6230., -1368.)	0.3	85.3	0.107	0.03
(-3500., -2500.)	(5791., -1609.)	0.3	83.4	0.065	0.02
(-3500., -2000.)	(5353., -1850.)	0.3	81.6	0.033	0.01
(-3000., -9500.)	(11685., 2202.)	0.0	80.2	0.004	0.0
(-3000., -9000.)	(11247., 1961.)	36.5	81.6	0.033	1.19
(-3000., -8500.)	(10808., 1720.)	36.5	82.9	0.058	2.11
(-3000., -8000.)	(10370., 1479.)	36.5	84.3	0.087	3.18
(-3000., -7500.)	(9932., 1238.)	36.5	85.9	0.117	4.29
(-3000., -7000.)	(9494., 997.)	31.6	87.5	0.151	4.77
(-3000., -6500.)	(9056., 756.)	31.6	89.7	0.194	6.14
(-3000., -6000.)	(8618., 515.)	31.6	92.2	0.245	7.74
(-3000., -5500.)	(8180., 275.)	31.6	94.4	0.289	9.12
(-3000., -5000.)	(7741., 34.)	31.6	96.9	0.338	10.67
(-3000., -4500.)	(7303., -207.)	31.6	96.2	0.324	10.24
(-3000., -4000.)	(6865., -448.)	31.6	94.6	0.296	9.34

C O M M U N I T Y   N O I S E   I M P A C T

AIRPORT — SNA - ORANGE CO. (SANTA ANA)

RUNWAY — 19R
RUNWAY COORDINATES — (700.,   1600.) FEET RELATIVE TO AIRPORT REFERENCE POINT
RUNWAY ANGLE — 241.2 DEGREES MEASURED COUNTERCLOCKWISE FROM EAST-WEST LINE

COORDS REL TO AIRPORT REF PT	COORDS REL TO RUNWAY BR PT	POPULATION	EPNL	ANNOYANCE FACTOR	NOISE IMPACT
(-3000., -3500.)	(6427., -689.)	0.3	92.6	0.256	0.08
(-3000., -3000.)	(5989., -930.)	0.3	90.2	0.205	0.06
(-3000., -2500.)	(5551., -1171.)	0.3	87.6	0.152	0.05
(-3000., -2000.)	(5112., -1412.)	0.3	85.0	0.099	0.03
(-3000., -1500.)	(4674., -1653.)	0.3	82.7	0.053	0.02
(-3000., -1000.)	(4236., -1893.)	0.3	80.6	0.012	0.00
(-2500., -8500.)	(10568., 2158.)	36.5	80.1	0.003	0.10
(-2500., -8000.)	(10129., 1917.)	36.5	81.4	0.029	1.06
(-2500., -7500.)	(9691., 1676.)	31.6	83.1	0.061	1.94
(-2500., -7000.)	(9253., 1435.)	31.6	84.8	0.096	3.02
(-2500., -6500.)	(8815., 1194.)	31.6	86.4	0.129	4.06
(-2500., -6000.)	(8377., 954.)	31.6	88.7	0.174	5.46
(-2500., -5500.)	(7939., 713.)	31.6	91.3	0.225	7.11
(-2500., -5000.)	(7500., 472.)	31.6	94.0	0.279	8.83
(-2500., -4500.)	(7062., 231.)	31.6	96.3	0.325	10.27
(-2500., -4000.)	(6624., -10.)	0.3	98.9	0.378	0.11
(-2500., -3500.)	(6186., -251.)	0.3	97.8	0.356	0.11
(-2500., -3000.)	(5748., -492.)	0.3	96.4	0.327	0.10
(-2500., -2500.)	(5310., -733.)	0.3	93.3	0.265	0.08
(-2500., -2000.)	(4872., -973.)	0.3	89.4	0.188	0.06
(-2500., -1500.)	(4433., -1214.)	0.3	86.5	0.131	0.04
(-2500., -1000.)	(3995., -1455.)	0.3	83.8	0.076	0.02
(-2500., -500.)	(3557., -1696.)	0.3	81.6	0.031	0.01
(-2000., -7000.)	(9012., 1873.)	31.6	81.0	0.020	0.65
(-2000., -6500.)	(8574., 1633.)	31.6	82.6	0.055	1.67
(-2000., -6000.)	(8136., 1392.)	31.6	84.4	0.089	2.81
(-2000., -5500.)	(7698., 1151.)	31.6	86.8	0.137	4.33
(-2000., -5000.)	(7260., 910.)	31.6	89.5	0.190	5.99
(-2000., -4500.)	(6821., 669.)	0.3	92.5	0.250	0.07
(-2000., -4000.)	(6383., 428.)	0.3	95.8	0.316	0.09
(-2000., -3500.)	(5945., 187.)	0.3	99.0	0.379	0.11
(-2000., -3000.)	(5507., -54.)	0.3	101.3	0.427	0.13
(-2000., -2500.)	(5069., -294.)	0.3	99.4	0.389	0.12
(-2000., -2000.)	(4631., -535.)	0.3	96.5	0.330	0.10
(-2000., -1500.)	(4193., -776.)	0.3	92.3	0.247	0.07
(-2000., -1000.)	(3754., -1017.)	0.3	88.1	0.163	0.05
(-2000., -500.)	(3316., -1258.)	0.3	85.3	0.106	0.03
(-2000., 0.)	(2878., -1499.)	0.3	82.3	0.046	0.01

C O M M U N I T Y   N O I S E   I M P A C T

AIRPORT -- SNA - ORANGE CO. (SANTA ANA)

RUNWAY -- 19R
RUNWAY COORDINATES -- (700., 1800.) FEET RELATIVE TO AIRPORT REFERENCE POINT
RUNWAY ANGLE -- 241.2 DEGREES MEASURED COUNTERCLOCKWISE FROM EAST-WEST LINE

COORDS REL TO AIRPORT REF PT	COORDS REL TO RUNWAY BR PT	POPULATION	LPNL	ANNOYANCE FACTOR	NOISE IMPACT
(-1500., -6000.)	(7695., 1830.)	31.6	80.6	0.011	0.36
(-1500., -5500.)	(7457., 1569.)	31.6	82.3	0.046	1.46
(-1500., -5000.)	(7019., 1348.)	0.3	84.8	0.095	0.03
(-1500., -4500.)	(6581., 1107.)	0.3	87.7	0.155	0.05
(-1500., -4000.)	(6142., 866.)	0.3	90.9	0.218	0.07
(-1500., -3500.)	(5704., 625.)	0.3	94.6	0.292	0.09
(-1500., -3000.)	(5266., 385.)	0.3	98.1	0.365	0.11
(-1500., -2500.)	(4828., 144.)	0.3	101.7	0.435	0.13
(-1500., -2000.)	(4390., -97.)	0.3	103.4	0.468	0.14
(-1500., -1500.)	(3952., -338.)	0.3	99.9	0.399	0.12
(-1500., -1000.)	(3514., -579.)	0.3	95.3	0.307	0.09
(-1500., -500.)	(3075., -820.)	0.3	90.9	0.218	0.07
(-1500., 0.)	(2637., -1061.)	0.3	86.4	0.128	0.04
(-1500., 500.)	(2199., -1302.)	0.3	83.1	0.062	0.02
(-1000., -5000.)	(6778., 1786.)	0.3	81.1	0.023	0.01
(-1000., -4500.)	(6340., 1545.)	0.3	83.5	0.070	0.02
(-1000., -4000.)	(5902., 1304.)	0.3	86.2	0.124	0.04
(-1000., -3500.)	(5463., 1064.)	0.3	88.7	0.173	0.05
(-1000., -3000.)	(5025., 823.)	0.3	91.9	0.238	0.07
(-1000., -2500.)	(4587., 582.)	0.3	95.7	0.315	0.09
(-1000., -2000.)	(4149., 341.)	0.3	99.7	0.395	0.12
(-1000., -1500.)	(3711., 100.)	0.3	104.5	0.499	0.15
(-1000., -1000.)	(3273., -141.)	0.3	104.9	0.498	0.15
(-1000., -500.)	(2834., -382.)	0.3	99.3	0.386	0.12
(-1000., 0.)	(2396., -623.)	0.3	93.3	0.266	0.08
(-1000., 500.)	(1958., -863.)	0.3	88.2	0.164	0.05
(-1000., 1000.)	(1520., -1104.)	0.3	83.9	0.078	0.02
(-1000., 1500.)	(1082., -1345.)	0.3	82.8	0.057	0.02
(-1000., 2000.)	(644., -1586.)	0.3	83.0	0.060	0.02
(-1000., 2500.)	(206., -1827.)	0.3	82.2	0.044	0.01
(-500., -4500.)	(6099., 1984.)	0.3	80.4	0.009	0.00
(-500., -4000.)	(5661., 1743.)	0.3	82.5	0.050	0.01
(-500., -3500.)	(5223., 1502.)	0.3	84.1	0.083	0.02
(-500., -3000.)	(4784., 1261.)	0.3	86.3	0.126	0.04
(-500., -2500.)	(4346., 1020.)	0.3	88.5	0.169	0.05
(-500., -2000.)	(3908., 779.)	0.3	92.1	0.243	0.07
(-500., -1500.)	(3470., 538.)	0.3	96.0	0.320	0.10
(-500., -1000.)	(3032., 297.)	0.3	101.4	0.429	0.13

C O M M U N I T Y   N O I S E   I M P A C T

AIRPORT -- SNA - ORANGE CO. (SANTA ANA)

RUNWAY -- 19R
RUNWAY COORDINATES -- (700., 1800.) FEET RELATIVE TO AIRPORT REFERENCE POINT
RUNWAY ANGLE -- 241.2 DEGREES MEASURED COUNTERCLOCKWISE FROM EAST-WEST LINE

COORDS REL TO AIRPORT REF PT	COORDS REL TO RUNWAY BR PT	POPULATION	EPNL	ANNOYANCE FACTOR	NOISE IMPACT
(-500., -500.)	(2594., 56.)	0.3	108.5	0.571	0.17
(-500., 0.)	(2155., -184.)	0.3	105.2	0.504	0.15
(-500., 500.)	(1717., -425.)	0.3	96.9	0.339	0.10
(-500., 1000.)	(1279., -666.)	0.3	91.7	0.235	0.07
(-500., 1500.)	(841., -907.)	0.3	89.3	0.187	0.06
(-500., 2000.)	(403., -1148.)	0.3	88.2	0.164	0.05
(0., -3500.)	(4982., 1940.)	0.3	80.7	0.015	0.00
(0., -3000.)	(4543., 1699.)	0.3	82.2	0.045	0.01
(0., -2500.)	(4105., 1458.)	0.3	83.9	0.077	0.02
(0., -2000.)	(3667., 1217.)	0.3	86.0	0.120	0.04
(0., -1500.)	(3229., 976.)	0.3	88.3	0.166	0.05
(0., -1000.)	(2791., 736.)	0.3	92.0	0.239	0.07
(0., -500.)	(2353., 495.)	0.3	95.6	0.311	0.09
(0., 0.)	(1915., 254.)	0.3	103.0	0.459	0.14
(0., 500.)	(1476., 13.)	0.3	111.7	0.634	0.19
(0., 1000.)	(1038., -228.)	0.3	105.4	0.508	0.15
(0., 1500.)	(600., -469.)	0.3	99.2	0.385	0.12
(0., 2000.)	(162., -710.)	0.3	95.1	0.302	0.09
(0., 2500.)	(-276., -951.)	0.3	83.0	0.059	0.02
(0., 3000.)	(-714., -1192.)	0.3	80.4	0.007	0.00
(500., -2500.)	(3864., 1896.)	0.3	80.3	0.006	0.00
(500., -2000.)	(3426., 1655.)	0.3	81.6	0.035	0.01
(500., -1500.)	(2988., 1415.)	0.3	83.4	0.068	0.02
(500., -1000.)	(2550., 1174.)	0.3	85.1	0.102	0.03
(500., -500.)	(2112., 933.)	0.3	87.3	0.145	0.04
(500., 0.)	(1674., 692.)	0.3	90.8	0.216	0.06
(500., 500.)	(1236., 451.)	0.3	96.7	0.333	0.10
(500., 1000.)	(797., 210.)	0.3	107.4	0.546	0.16
(500., 1500.)	(359., -31.)	0.3	115.8	0.715	0.21
(500., 2000.)	(-79., -272.)	0.3	98.2	0.365	0.11
(500., 2500.)	(-517., -512.)	0.3	91.5	0.230	0.07
(500., 3000.)	(-955., -753.)	0.3	87.6	0.151	0.05
(500., 3500.)	(-1393., -994.)	0.3	83.7	0.074	0.02
(500., 4000.)	(-1832., -1235.)	2.7	81.1	0.022	0.06
(1000., -1000.)	(2309., 1612.)	0.3	80.4	0.008	0.00
(1000., -500.)	(1871., 1371.)	0.3	81.7	0.035	0.01
(1000., 0.)	(1433., 1130.)	0.3	83.9	0.077	0.02
(1000., 500.)	(995., 889.)	0.3	88.7	0.175	0.05

C O M M U N I T Y   N O I S E   I M P A C T

AIRPORT -- SNA - ORANGE CO. (SANTA ANA)

RUNWAY -- 19R
RUNWAY COORDINATES -- (700., 1800.) FEET RELATIVE TO AIRPORT REFERENCE POINT
RUNWAY ANGLE -- 241.2 DEGREES MEASURED COUNTERCLOCKWISE FROM EAST-WEST LINE

COORDS REL TO AIRPORT REF PT	COORDS REL TO RUNWAY BR PT	POPULATION	EPNL	ANNOYANCE FACTOR	NOISE IMPACT
(1000., 1000.)	(557., 648.)	0.3	95.7	0.314	0.09
(1000., 1500.)	(118., 407.)	0.3	102.2	0.444	0.13
(1000., 2000.)	(-320., 167.)	0.3	101.3	0.426	0.13
(1000., 2500.)	(-758., -74.)	0.3	103.2	0.463	0.14
(1000., 3000.)	(-1196., -315.)	0.3	96.7	0.333	0.10
(1000., 3500.)	(-1634., -556.)	0.3	91.6	0.233	0.07
(1000., 4000.)	(-2072., -797.)	2.7	87.7	0.153	0.41
(1000., 4500.)	(-2511., -1038.)	2.7	84.0	0.079	0.21
(1000., 5000.)	(-2949., -1279.)	2.7	81.3	0.027	0.07
(1500., 500.)	(754., 1327.)	0.3	84.8	0.096	0.03
(1500., 1000.)	(316., 1086.)	0.3	88.9	0.178	0.05
(1500., 1500.)	(-123., 846.)	0.3	84.6	0.092	0.03
(1500., 2000.)	(-561., 605.)	0.3	89.8	0.197	0.06
(1500., 2500.)	(-999., 364.)	0.3	95.5	0.311	0.09
(1500., 3000.)	(-1437., 123.)	0.3	100.8	0.415	0.12
(1500., 3500.)	(-1875., -118.)	2.7	100.0	0.400	1.08
(1500., 4000.)	(-2313., -359.)	2.7	95.3	0.305	0.82
(1500., 4500.)	(-2751., -600.)	2.7	91.3	0.220	0.61
(1500., 5000.)	(-3190., -841.)	2.7	87.3	0.146	0.39
(1500., 5500.)	(-3628., -1081.)	2.7	83.9	0.079	0.21
(1500., 6000.)	(-4066., -1322.)	2.7	81.3	0.026	0.07
(2000., 500.)	(513., 1765.)	0.3	82.5	0.049	0.01
(2000., 1000.)	(75., 1525.)	0.3	84.5	0.090	0.03
(2000., 2000.)	(-802., 1043.)	0.3	82.4	0.047	0.01
(2000., 2500.)	(-1240., 802.)	0.3	87.0	0.139	0.04
(2000., 3000.)	(-1678., 561.)	0.3	91.6	0.231	0.07
(2000., 3500.)	(-2116., 320.)	2.7	96.0	0.320	0.86
(2000., 4000.)	(-2554., 79.)	2.7	99.2	0.385	1.04
(2000., 4500.)	(-2992., -162.)	2.7	97.3	0.346	0.93
(2000., 5000.)	(-3430., -402.)	2.7	93.8	0.275	0.74
(2000., 5500.)	(-3869., -643.)	2.7	90.2	0.204	0.55
(2000., 6000.)	(-4307., -884.)	2.7	86.6	0.132	0.36
(2000., 6500.)	(-4745., -1125.)	2.7	83.4	0.068	0.18
(2000., 7000.)	(-5183., -1366.)	12.8	80.3	0.006	0.08
(2500., 2500.)	(-1481., 1240.)	0.3	80.7	0.015	0.00
(2500., 3000.)	(-1919., 999.)	2.7	84.0	0.081	0.22
(2500., 3500.)	(-2357., 758.)	2.7	88.5	0.170	0.46
(2500., 4000.)	(-2795., 517.)	2.7	92.7	0.254	0.69

COMMUNITY NOISE IMPACT

AIRPORT -- SNA - ORANGE CO. (SANTA ANA)

RUNWAY -- 19R
RUNWAY COORDINATES -- (700., 1800.) FEET RELATIVE TO AIRPORT REFERENCE POINT
RUNWAY ANGLE -- 241.2 DEGREES MEASURED COUNTERCLOCKWISE FROM EAST-WEST LINE

COORDS REL TO AIRPORT REF PT	COORDS REL TO RUNWAY BK PT	POPULATION	EPNL	ANNOYANCE FACTOR	NOISE IMPACT
(2500., 4500.)	(-3233., 277.)	2.7	95.5	0.310	0.84
(2500., 5000.)	(-3671., 36.)	2.7	97.6	0.352	0.95
(2500., 5500.)	(-4109., -205.)	2.7	95.0	0.301	0.81
(2500., 6000.)	(-4548., -446.)	2.7	92.0	0.239	0.65
(2500., 6500.)	(-4986., -687.)	2.7	88.4	0.168	0.45
(2500., 7000.)	(-5424., -928.)	2.7	85.3	0.105	0.28
(2500., 7500.)	(-5862., -1169.)	2.7	82.2	0.044	0.12
(3000., 3500.)	(-2598., 1197.)	2.7	82.1	0.042	0.11
(3000., 4000.)	(-3036., 956.)	2.7	85.4	0.108	0.29
(3000., 4500.)	(-3474., 715.)	2.7	89.3	0.185	0.50
(3000., 5000.)	(-3912., 474.)	2.7	92.5	0.250	0.68
(3000., 5500.)	(-4350., 233.)	2.7	94.4	0.287	0.77
(3000., 6000.)	(-4789., -8.)	2.7	95.5	0.310	0.84
(3000., 6500.)	(-5227., -249.)	2.7	92.3	0.245	0.66
(3000., 7000.)	(-5665., -490.)	2.7	89.4	0.189	0.51
(3000., 7500.)	(-6103., -731.)	2.7	86.3	0.126	0.34
(3000., 8000.)	(-6541., -971.)	2.7	82.8	0.055	0.15
(3500., 4000.)	(-3277., 1394.)	2.7	80.2	0.003	0.01
(3500., 4500.)	(-3715., 1153.)	2.7	83.1	0.063	0.17
(3500., 5000.)	(-4153., 912.)	2.7	86.2	0.125	0.34
(3500., 5500.)	(-4591., 671.)	2.7	89.2	0.184	0.50
(3500., 6000.)	(-5029., 430.)	2.7	91.1	0.223	0.60
(3500., 6500.)	(-5468., 189.)	2.7	92.2	0.243	0.66
(3500., 7000.)	(-5906., -51.)	2.7	92.3	0.245	0.66
(3500., 7500.)	(-6344., -292.)	2.7	89.2	0.183	0.49
(3500., 8000.)	(-6782., -533.)	2.7	85.3	0.106	0.29
(3500., 8500.)	(-7220., -774.)	2.7	80.4	0.009	0.02
(4000., 5000.)	(-4394., 1350.)	2.7	81.0	0.019	0.05
(4000., 5500.)	(-4832., 1109.)	2.7	83.5	0.071	0.19
(4000., 6000.)	(-5270., 868.)	2.7	86.0	0.121	0.33
(4000., 6500.)	(-5708., 628.)	2.7	88.0	0.160	0.43
(4000., 7000.)	(-6147., 387.)	2.7	89.2	0.183	0.49
(4000., 7500.)	(-6585., 146.)	2.7	89.1	0.182	0.49
(4000., 8000.)	(-7023., -95.)	2.7	86.6	0.135	0.36
(4000., 8500.)	(-7461., -336.)	2.7	81.9	0.037	0.10
(4500., 6000.)	(-5511., 1307.)	2.7	80.8	0.016	0.04
(4500., 6500.)	(-5949., 1066.)	2.7	83.3	0.066	0.18
(4500., 7000.)	(-6387., 825.)	2.7	84.6	0.092	0.25

C O M M U N I T Y   N O I S E   I M P A C T

AIRPORT -- SNA - ORANGE CO. (SANTA ANA)

RUNWAY -- 19R
RUNWAY COORDINATES -- (700., 1800.) FEET RELATIVE TO AIRPORT REFERENCE POINT
RUNWAY ANGLE -- 241.2 DEGREES MEASURED COUNTERCLOCKWISE FROM EAST-WEST LINE

COORDS REL TO AIRPORT REF PT	COORDS REL TO RUNWAY BR PT	POPULATION	EPNL	ANNOYANCE FACTOR	NOISE IMPACT
(4500., 7500.)	(-6826., 584.)	2.7	64.6	0.092	0.25
(4500., 8000.)	(-7264., 343.)	2.7	63.3	0.066	0.18
(4500., 8500.)	(-7702., 102.)	2.7	62.2	0.045	0.12
(4500., 9000.)	(-8140., -139.)	2.7	60.8	0.016	0.04
(5000., 9500.)	(-8819., 59.)	2.7	60.2	0.005	0.01

TOTAL POPULATION AFFECTED = 4862.4
TOTAL ANNOYANCE = 51.66
TOTAL NOISE IMPACT = 468.41

APPENDIX

C.3 Aircraft Noise Contours

This appendix contains some of the noise contours which correspond to the operational procedures which were evaluated at each airport. Table C-1 and C-2 lists the operating parameters which were varied for each operational procedure. Figures C-5 through C-28 are the noise contours corresponding to the operational procedures evaluated for the E-150-3000 aircraft. Figures C-29 through C-37 are some of the noise contours corresponding to the operational procedures evaluated for the M-150-4000 aircraft.

TABLE C-1

VARIATIONS OF TAKEOFF OPERATIONAL PROCEDURES

Externally Blown Flap - 150 Passengers - 3000 Ft. (915 m) Field Length

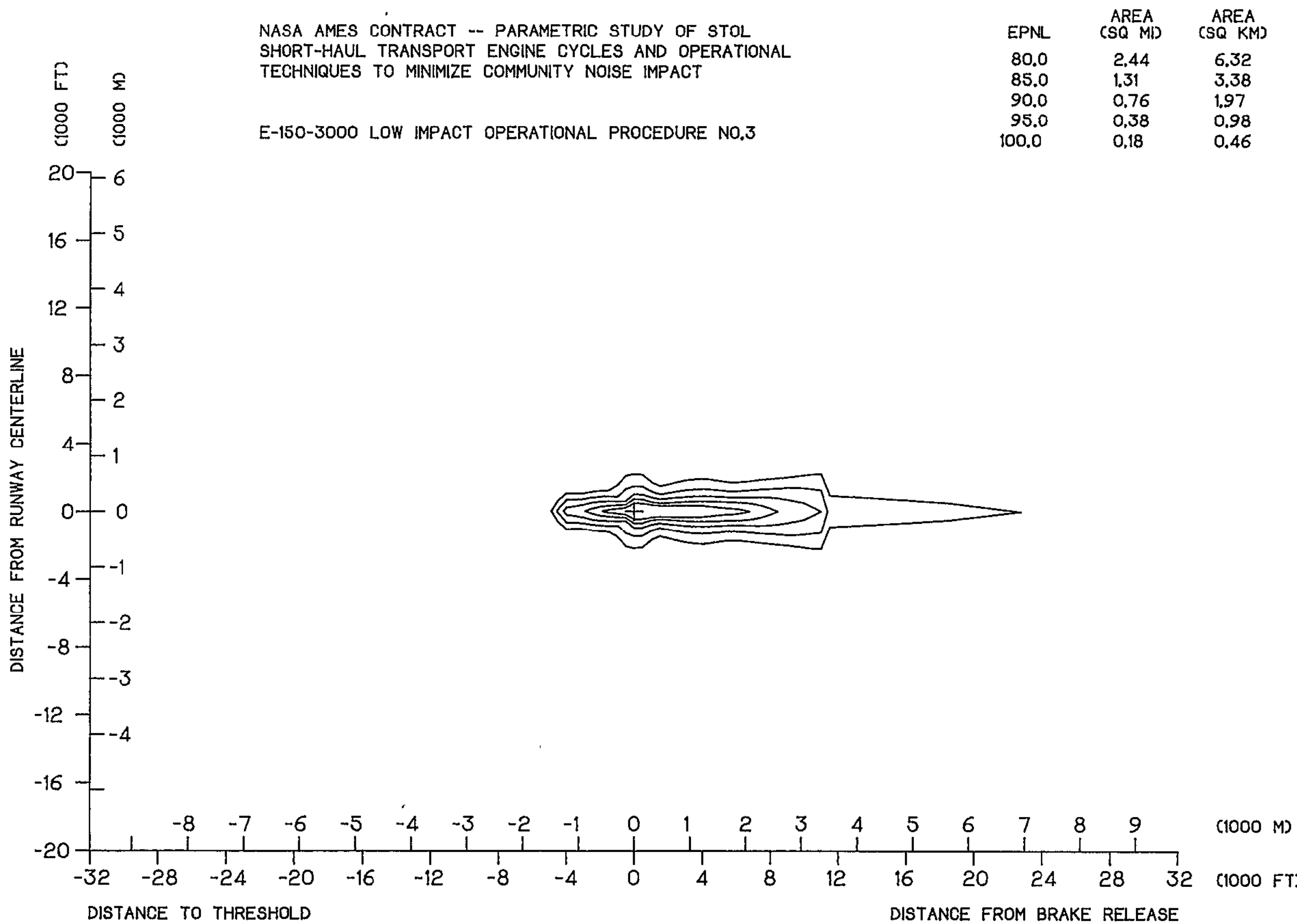
	Flap Retraction	Power Cutback		Turn	
Operational Procedure	Height ft (m)	Level %	Height ft (m)	Angle Deg (Rad)	Height ft (m)
1	200 (61)	64	750 (229)	---	---
2	200 (61)	64	1000 (305)	---	---
3	200 (61)	64	1200 (366)	---	---
4	200 (61)	64	1500 (457)	45 (.785)	500 (152)
5	200 (61)	64	1750 (534)	45 (.785)	750 (229)
6	200 (61)	64	1975 (602)	45 (.785)	1000 (305)
7	200 (61)	64	1150 (351)	20 (.349)	500 (152)
8	200 (61)	64	1400 (427)	20 (.349)	750 (229)
9	200 (61)	64	1275 (389)	30 (.524)	500 (152)
10	200 (61)	64	1525 (465)	30 (.524)	750 (229)
11	200 (61)	64	500 (152)	20 (.349)	550 (168)
12	200 (61)	70	500 (152)	---	---
13	200 (61)	70	750 (229)	---	---
14	200 (61)	64	750 (229)	20 (.349)	800 (244)
15	200 (61)	64	1000 (349	20 (.349)	1050 (320)
16	200 (61)	64	1775 (541)	30 (.524)	1000 (305)
17	200 (61)	64	1600 (488)	---	---
18	200 (61)	64	2000 (610)	---	---
19	200 (61)	64	500 (152)	---	---
20	200 (61)	64	500 (152)	---	---
	200 (61)	82	800 (244)	---	---
21	200 (61)	64	500 (152)	45 (.785)	800 (244)
22	200 (61)	82	500 (152)	---	---
23	200 (61)	70	1000 (305)	---	---
24	200 (61)	64	1000 (305)	20 (.349)	800 (244)
25	200 (61)	64	500 (152)	45 (.785)	550 (168)
26	200 (61)	64	500 (152)	45 (.785)	600 (183)
27	200 (61)	64	500 (152)	45 (.785)	700 (213)

TABLE C-2

VARIATION OF TAKEOFF OPERATIONAL PROCEDURES

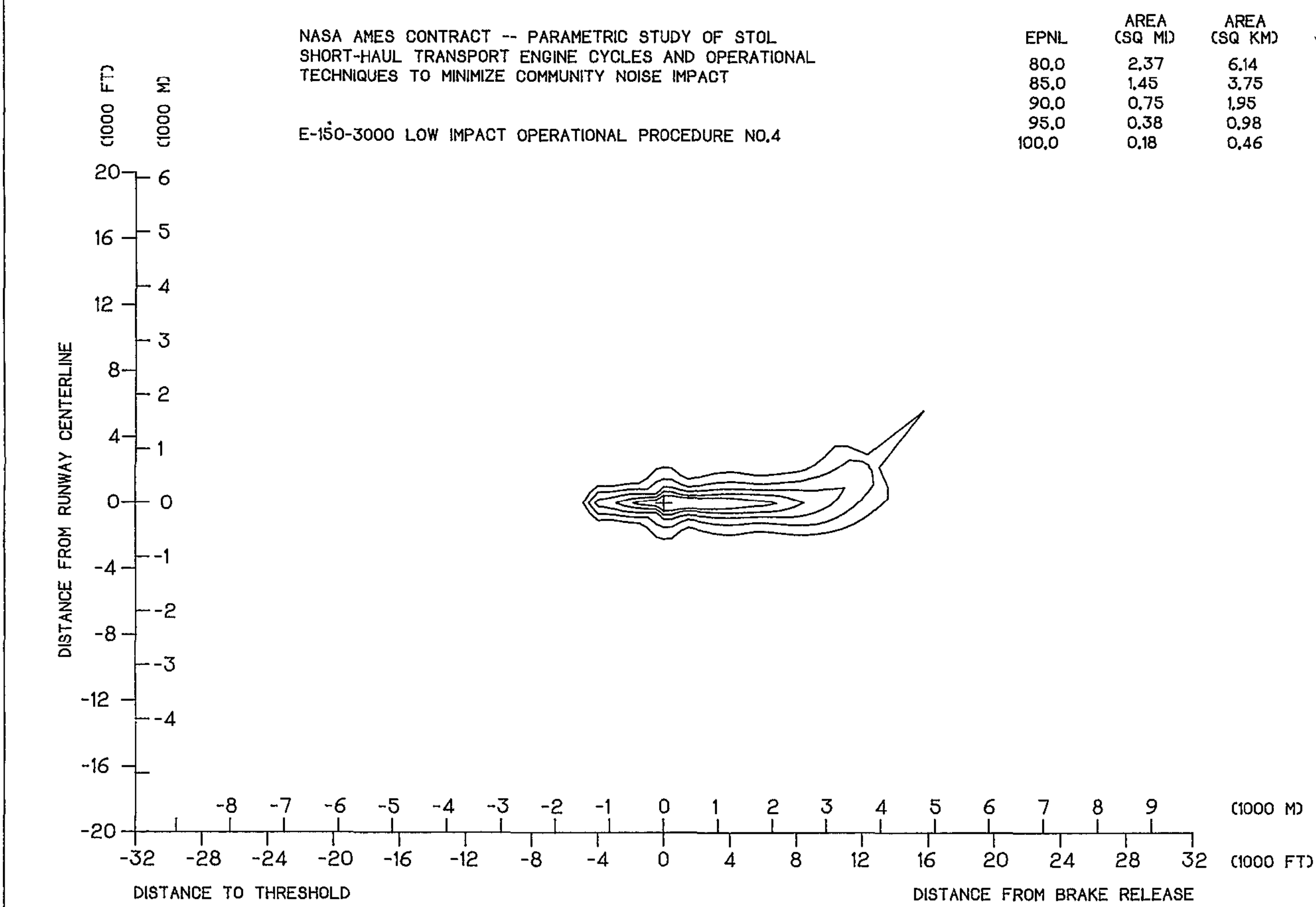
Mechanical Flap - 150 Passengers - 4000 Ft. (1219 m) Field Length

	Flap Retraction	Power Cutback		Turn	
Operational Procedure	Height ft (m)	Level %	Height ft (m)	Angle Deg (Rad)	Height ft (m)
1	400 (122)	66	1000 (305)	---	---
2	300 (91)	66	500 (152)	---	---
3	300 (91)	66	750 (229)	---	---
4	300 (91)	66	1000 (305)	---	---
5	500 (152)	66	1000 (305)	---	---
6	250 (76)	66	1000 (305)	---	---
7	250 (76)	66	750 (229)	---	---
8	250 (76)	66	500 (152)	---	---
9	250 (76)	70	1000 (305)	---	---
10	250 (76)	70	750 (229)	---	---
11	250 (76)	70	500 (152)	---	---
12	250 (76)	66	500 (152)	20 (.349)	550 (168)
13	250 (76)	66	750 (229)	20 (.349)	800 (244)
14	250 (76)	66	1000 (305)	20 (.349)	1050 (320)
15	300 (91)	66	500 (152)	45 (.785)	550 (168)
16	300 (91)	66	500 (152)	45 (.785)	600 (183)
17	300 (91)	66	500 (152)	45 (.785)	700 (213)
18	300 (91)	66	500 (152)	45 (.785)	800 (244)
19	300 (91)	66	500 (152)	45 (.785)	900 (274)
20	250 (76)	66	1450 (442)	30 (.524)	500 (152)
21	250 (76)	66	1950 (596)	30 (.524)	1000 (305)
22	250 (76)	66	1700 (518)	30 (.524)	750 (229)



NASA AMES CONTRACT -- PARAMETRIC STUDY OF STOL SHORT-HAUL TRANSPORT ENGINE CYCLES AND OPERATIONAL TECHNIQUES TO MINIMIZE COMMUNITY NOISE IMPACT
E-150-3000 LOW IMPACT OPERATIONAL PROCEDURE NO.3
EPNL | AREA (SQ MI) | AREA (SQ KM)
80.0 | 2.44 | 6.32
85.0 | 1.31 | 3.38
90.0 | 0.76 | 1.97
95.0 | 0.38 | 0.98
100.0 | 0.18 | 0.46
DISTANCE FROM RUNWAY CENTERLINE
(1000 FT)
(1000 M)
DISTANCE TO THRESHOLD
DISTANCE FROM BRAKE RELEASE

FIGURE C-5.



NASA AMES CONTRACT -- PARAMETRIC STUDY OF STOL
SHORT-HAUL TRANSPORT ENGINE CYCLES AND OPERATIONAL
TECHNIQUES TO MINIMIZE COMMUNITY NOISE IMPACT
E-150-3000 LOW IMPACT OPERATIONAL PROCEDURE NO.4
EPNL
AREA (SQ MI)
AREA (SQ KM)
80.0 2.37 6.14
85.0 1.45 3.75
90.0 0.75 1.95
95.0 0.38 0.98
100.0 0.18 0.46
(1000 FT)
(1000 M)
DISTANCE FROM RUNWAY CENTERLINE
20 16 12 8 4 0 -4 -8 -12 -16 -20
6 5 4 3 2 1 0 -1 -2 -3 -4
-8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 (1000 M)
-32 -28 -24 -20 -16 -12 -8 -4 0 4 8 12 16 20 24 28 32 (1000 FT)
DISTANCE TO THRESHOLD
DISTANCE FROM BRAKE RELEASE

FIGURE C-6.

NASA AMES CONTRACT -- PARAMETRIC STUDY OF STOL SHORT-HAUL TRANSPORT ENGINE CYCLES AND OPERATIONAL TECHNIQUES TO MINIMIZE COMMUNITY NOISE IMPACT

E-150-3000 LOW IMPACT OPERATIONAL PROCEDURE NO.5

EPNL	AREA (SQ MI)	AREA (SQ KM)
80.0	2.45	6.36
85.0	1.51	3.92
90.0	0.75	1.94
95.0	0.38	0.98
100.0	0.18	0.46

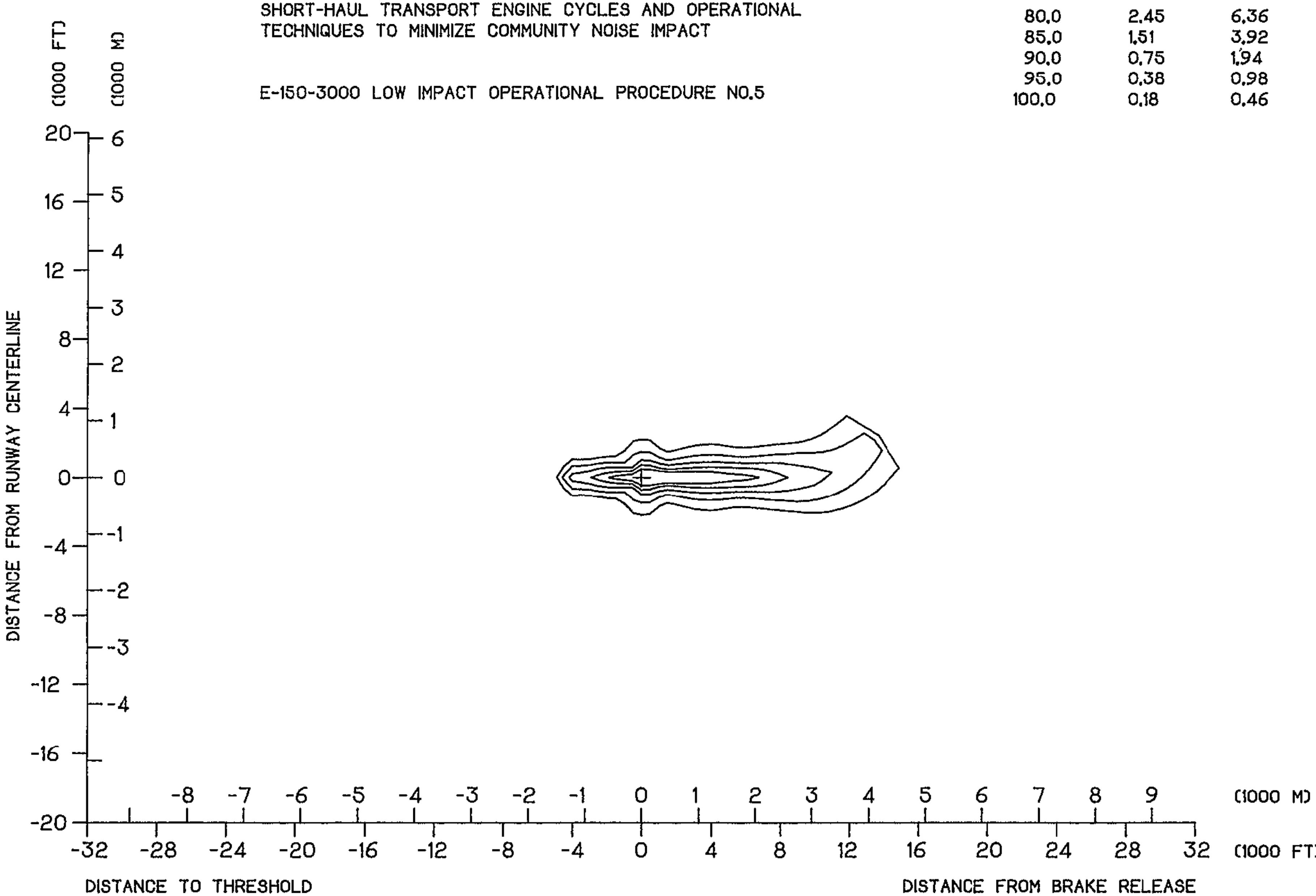


FIGURE C-7.

NASA AMES CONTRACT -- PARAMETRIC STUDY OF STOL
SHORT-HAUL TRANSPORT ENGINE CYCLES AND OPERATIONAL
TECHNIQUES TO MINIMIZE COMMUNITY NOISE IMPACT

E-150-3000 LOW IMPACT OPERATIONAL PROCEDURE NO.6

EPNL	AREA (SQ MI)	AREA (SQ KM)
80.0	2.74	7.09
85.0	1.57	4.06
90.0	0.76	1.97
95.0	0.38	0.98
100.0	0.18	0.46

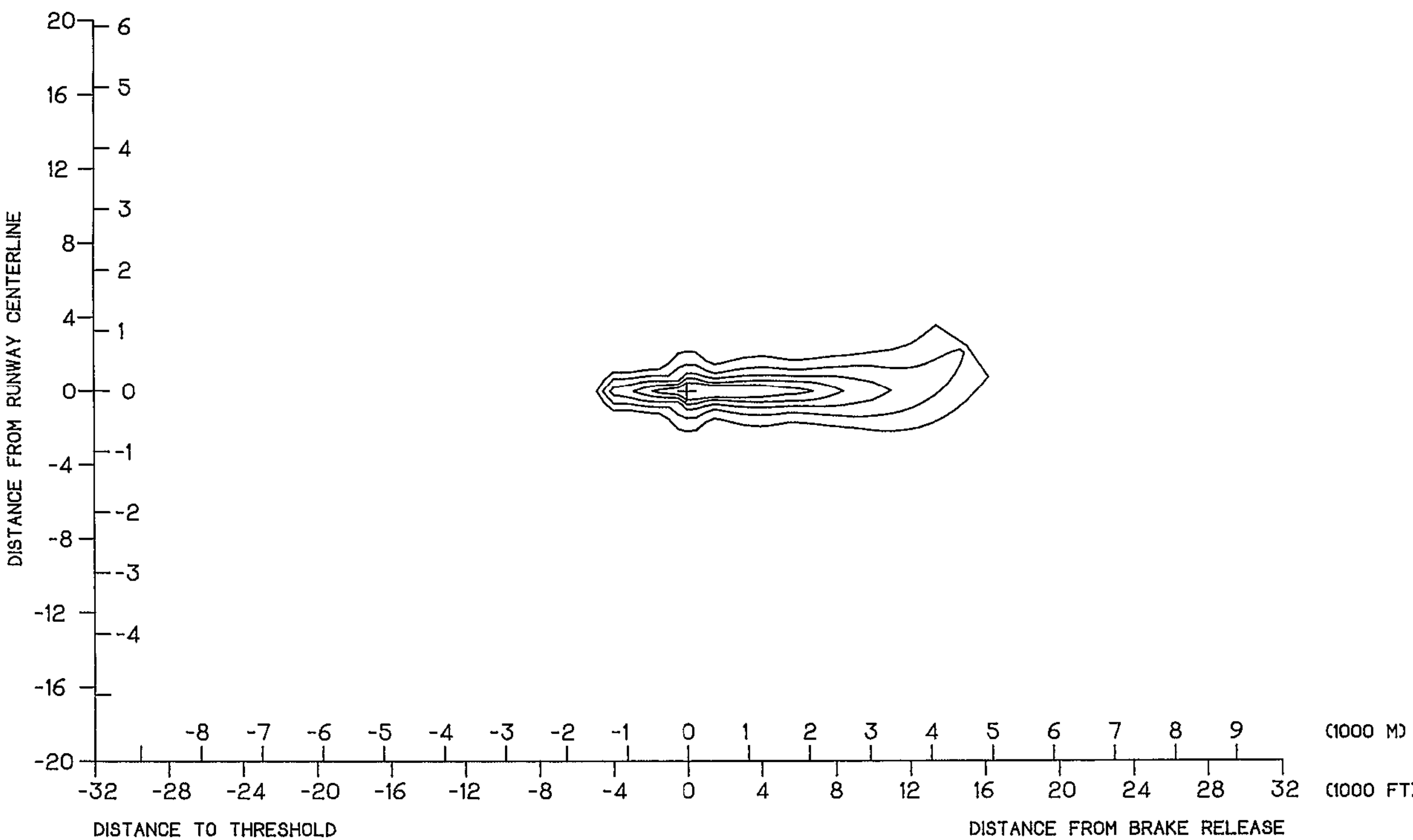


FIGURE C-8.

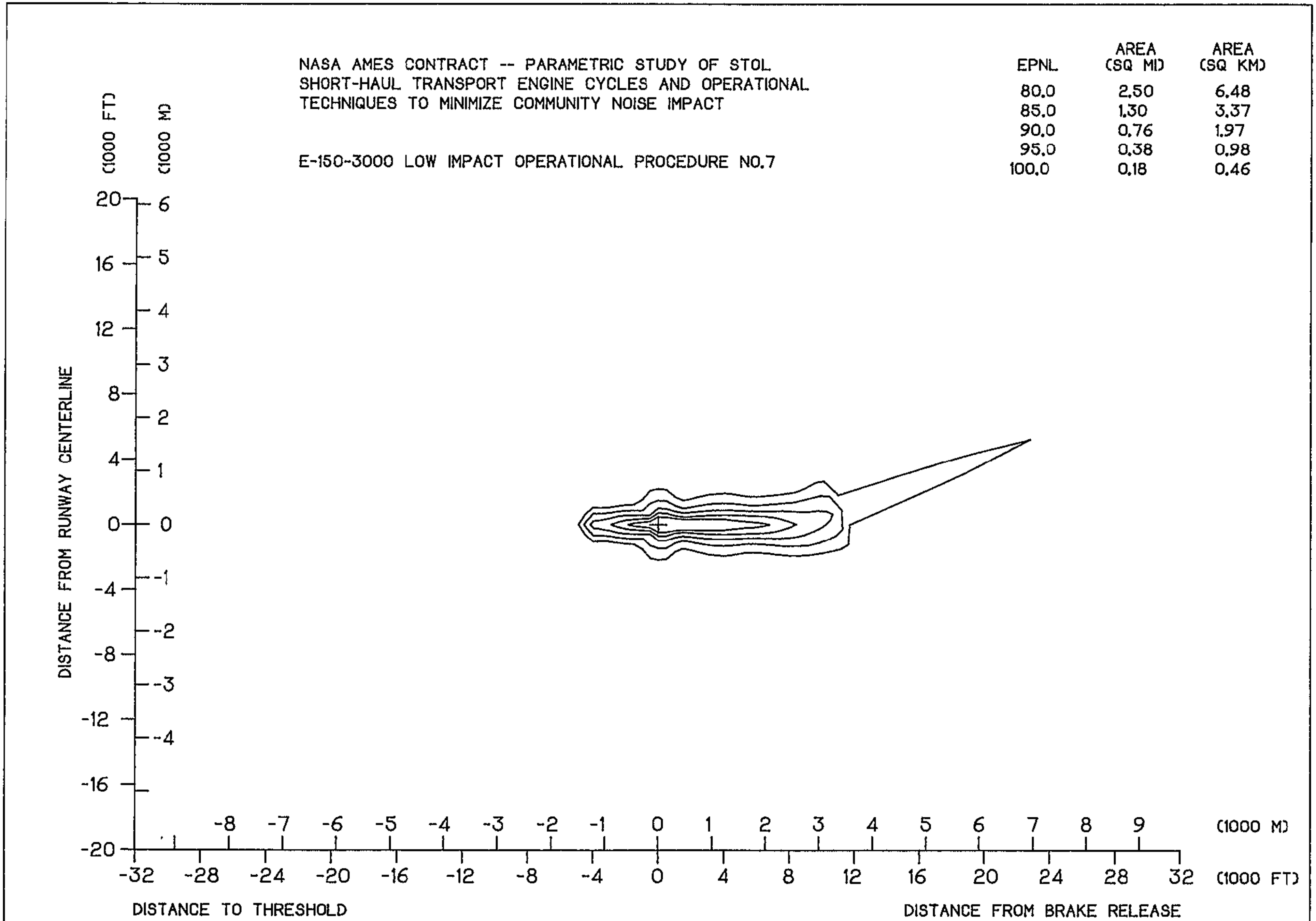

NASA AMES CONTRACT -- PARAMETRIC STUDY OF STOL
SHORT-HAUL TRANSPORT ENGINE CYCLES AND OPERATIONAL
TECHNIQUES TO MINIMIZE COMMUNITY NOISE IMPACT
E-150-3000 LOW IMPACT OPERATIONAL PROCEDURE NO.7
EPNL
AREA (SQ MI)
AREA (SQ KM)
80.0 2.50 6.48
85.0 1.30 3.37
90.0 0.76 1.97
95.0 0.38 0.98
100.0 0.18 0.46
(1000 FT)
(1000 M)
DISTANCE FROM RUNWAY CENTERLINE
20
16
12
8
4
0
-4
-8
-12
-16
-20
6
5
4
3
2
1
0
-1
-2
-3
-4
-8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 (1000 M)
-32 -28 -24 -20 -16 -12 -8 -4 0 4 8 12 16 20 24 28 32 (1000 FT)
DISTANCE TO THRESHOLD
DISTANCE FROM BRAKE RELEASE

FIGURE C-9.

NASA AMES CONTRACT -- PARAMETRIC STUDY OF STOL SHORT-HAUL TRANSPORT ENGINE CYCLES AND OPERATIONAL TECHNIQUES TO MINIMIZE COMMUNITY NOISE IMPACT

E-150-3000 LOW IMPACT OPERATIONAL PROCEDURE NO.8

EPNL	AREA (SQ MI)	AREA (SQ KM)
80.0	2.36	6.10
85.0	1.39	3.60
90.0	0.75	1.94
95.0	0.38	0.98
100.0	0.18	0.46

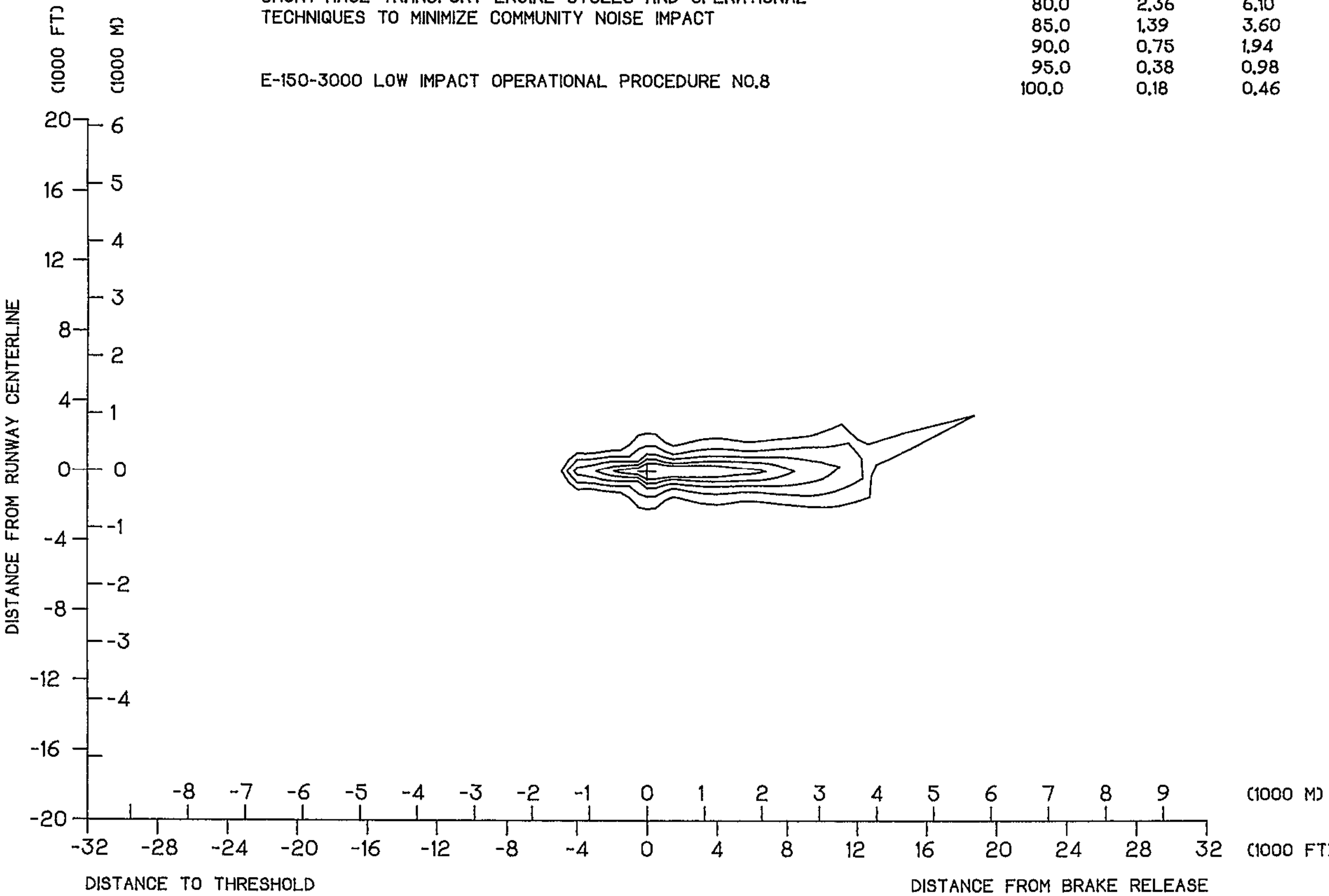


FIGURE C-10.

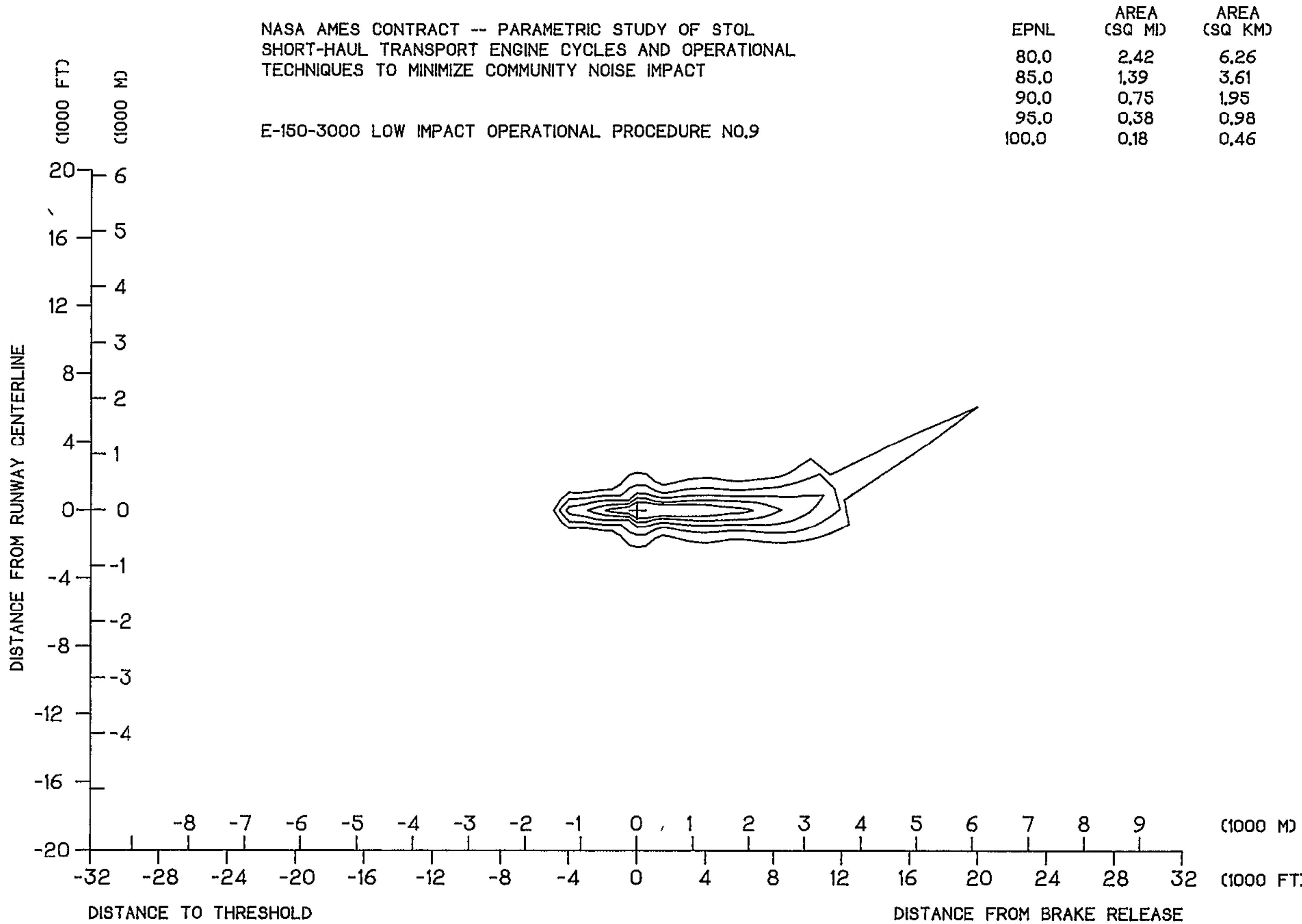

NASA AMES CONTRACT -- PARAMETRIC STUDY OF STOL
SHORT-HAUL TRANSPORT ENGINE CYCLES AND OPERATIONAL
TECHNIQUES TO MINIMIZE COMMUNITY NOISE IMPACT
E-150-3000 LOW IMPACT OPERATIONAL PROCEDURE NO.9
EPNL | AREA (SQ MI) | AREA (SQ KM)
80.0 | 2.42 | 6.26
85.0 | 1.39 | 3.61
90.0 | 0.75 | 1.95
95.0 | 0.38 | 0.98
100.0 | 0.18 | 0.46
(1000 FT)
(1000 M)
DISTANCE FROM RUNWAY CENTERLINE
20
16
12
8
4
0
-4
-8
-12
-16
-20
6
5
4
3
2
1
0
-1
-2
-3
-4
-8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 (1000 M)
-32 -28 -24 -20 -16 -12 -8 -4 0 4 8 12 16 20 24 28 32 (1000 FT)
DISTANCE TO THRESHOLD
DISTANCE FROM BRAKE RELEASE

FIGURE C-11.

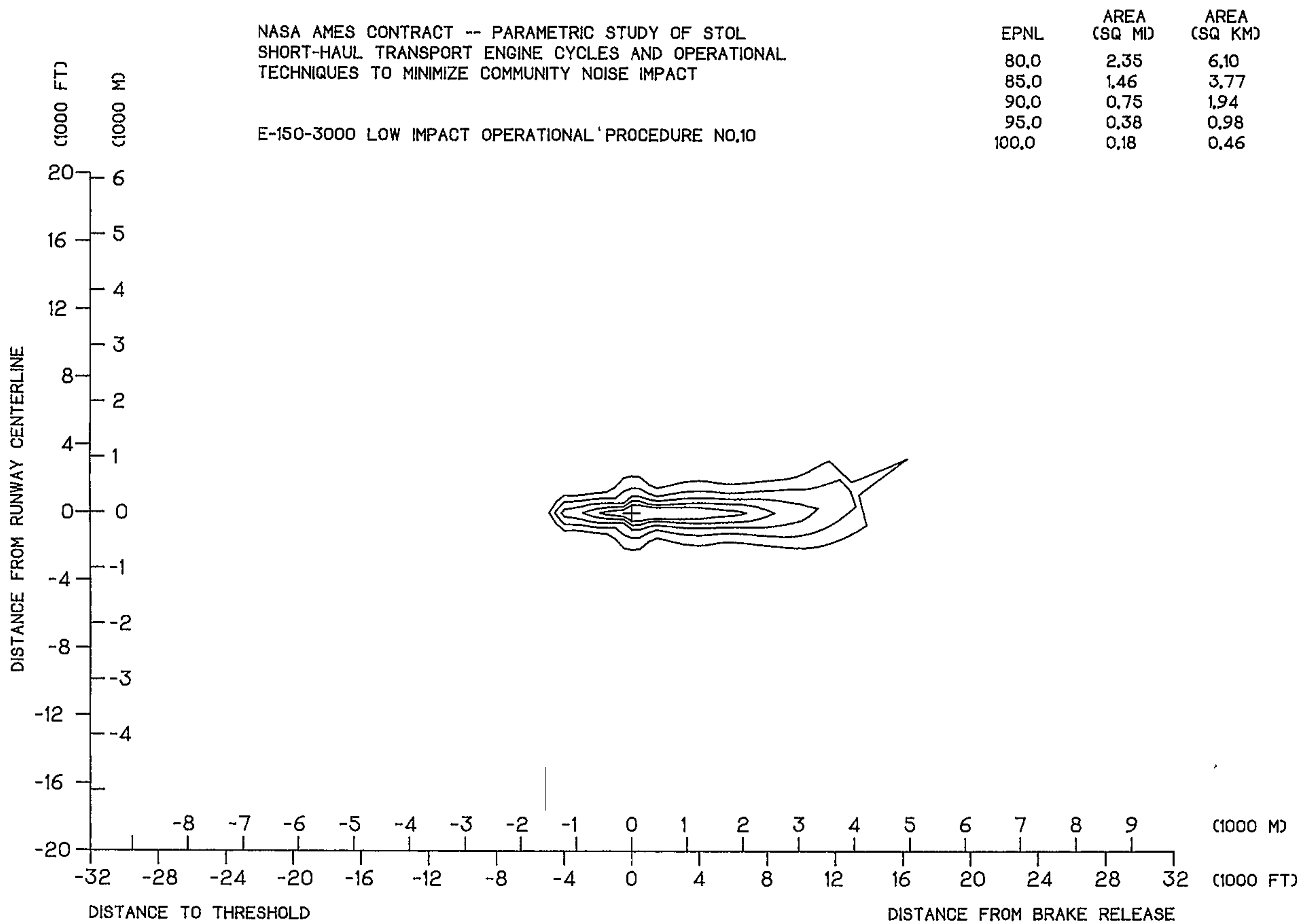
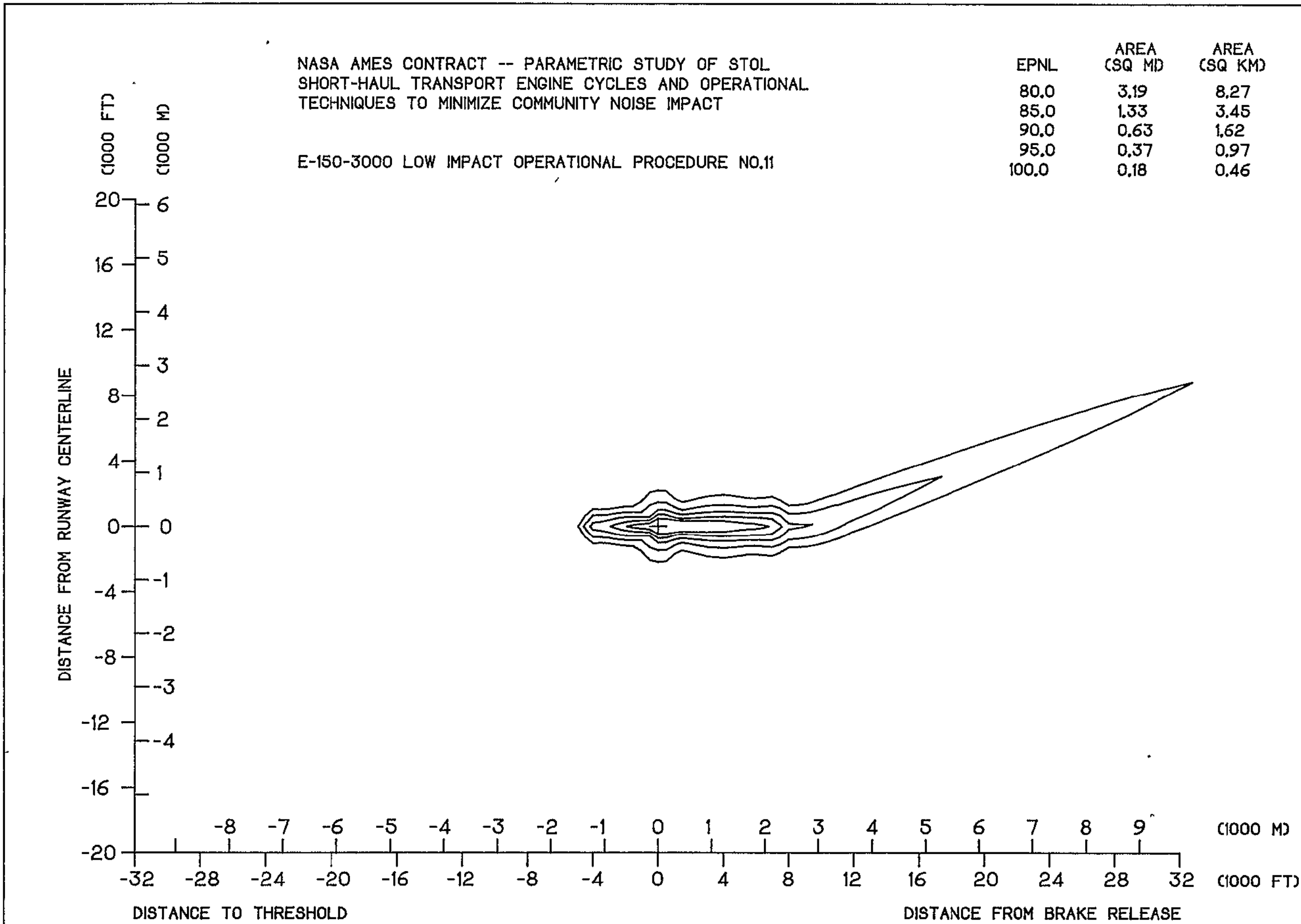

NASA AMES CONTRACT -- PARAMETRIC STUDY OF STOL
SHORT-HAUL TRANSPORT ENGINE CYCLES AND OPERATIONAL
TECHNIQUES TO MINIMIZE COMMUNITY NOISE IMPACT
E-150-3000 LOW IMPACT OPERATIONAL PROCEDURE NO.10
EPNL
AREA (SQ MI)
AREA (SQ KM)
80.0 2.35 6.10
85.0 1.46 3.77
90.0 0.75 1.94
95.0 0.38 0.98
100.0 0.18 0.46
(1000 FT)
(1000 M)
DISTANCE FROM RUNWAY CENTERLINE
20
16
12
8
4
0
-4
-8
-12
-16
-20
6
5
4
3
2
1
0
-1
-2
-3
-4
-8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 (1000 M)
-32 -28 -24 -20 -16 -12 -8 -4 0 4 8 12 16 20 24 28 32 (1000 FT)
DISTANCE TO THRESHOLD
DISTANCE FROM BRAKE RELEASE

FIGURE C-12.



NASA AMES CONTRACT -- PARAMETRIC STUDY OF STOL
SHORT-HAUL TRANSPORT ENGINE CYCLES AND OPERATIONAL
TECHNIQUES TO MINIMIZE COMMUNITY NOISE IMPACT
E-150-3000 LOW IMPACT OPERATIONAL PROCEDURE NO.11
EPNL
AREA (SQ MI)
AREA (SQ KM)
80.0 3.19 8.27
85.0 1.33 3.45
90.0 0.63 1.62
95.0 0.37 0.97
100.0 0.18 0.46
(1000 FT)
(1000 M)
DISTANCE FROM RUNWAY CENTERLINE
20
16
12
8
4
0
-4
-8
-12
-16
-20
6
5
4
3
2
1
0
-1
-2
-3
-4
-8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9
(1000 M)
-32 -28 -24 -20 -16 -12 -8 -4 0 4 8 12 16 20 24 28 32
(1000 FT)
DISTANCE TO THRESHOLD
DISTANCE FROM BRAKE RELEASE

FIGURE C-13.

NASA AMES CONTRACT -- PARAMETRIC STUDY OF STOL SHORT-HAUL TRANSPORT ENGINE CYCLES AND OPERATIONAL TECHNIQUES TO MINIMIZE COMMUNITY NOISE IMPACT

E-150-3000 LOW IMPACT OPERATIONAL PROCEDURE NO.12

EPNL	AREA (SQ MI)	AREA (SQ KM)
80.0	3.08	7.98
85.0	1.35	3.51
90.0	0.64	1.65
95.0	0.36	0.93
100.0	0.18	0.46

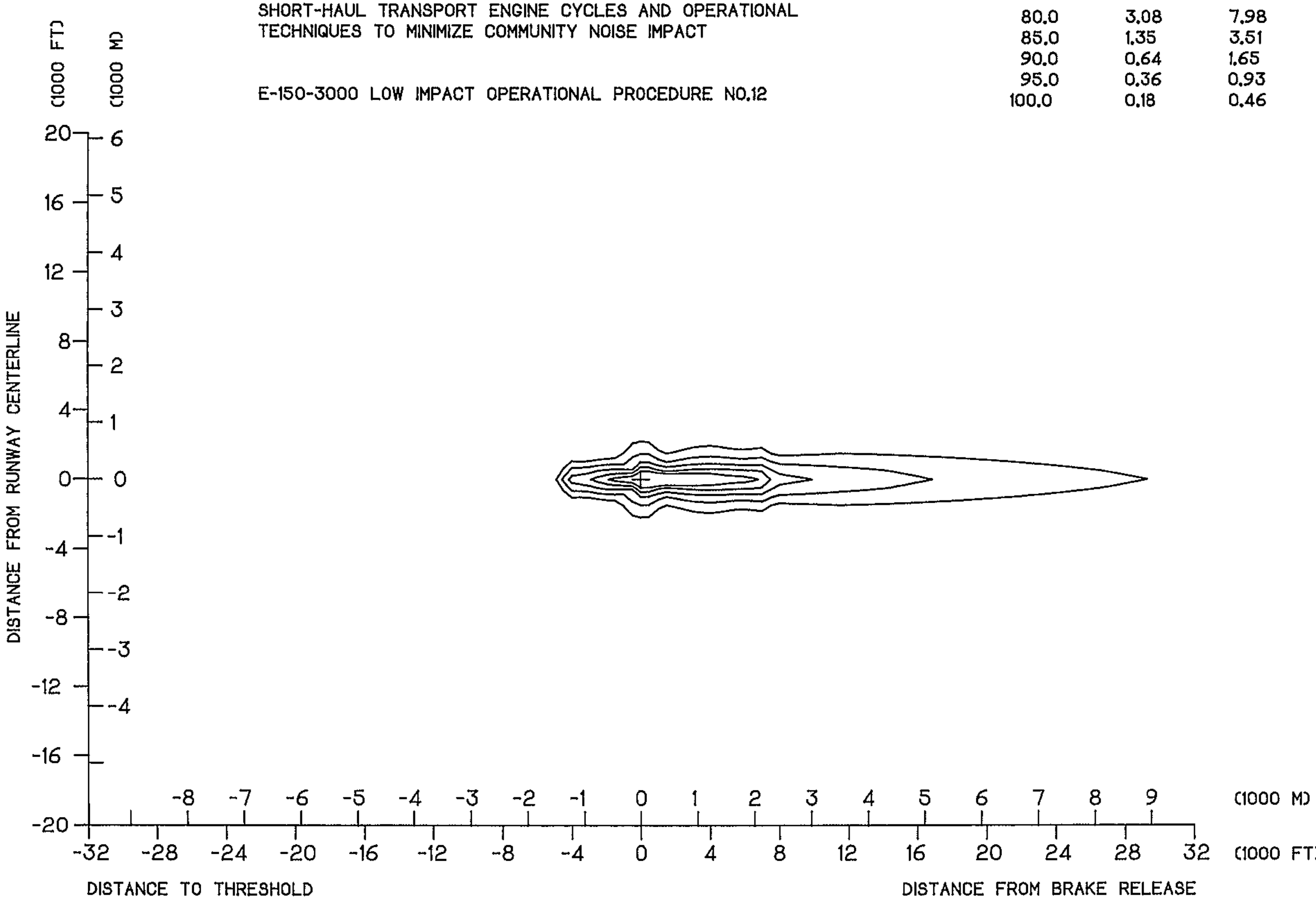


FIGURE C-14.

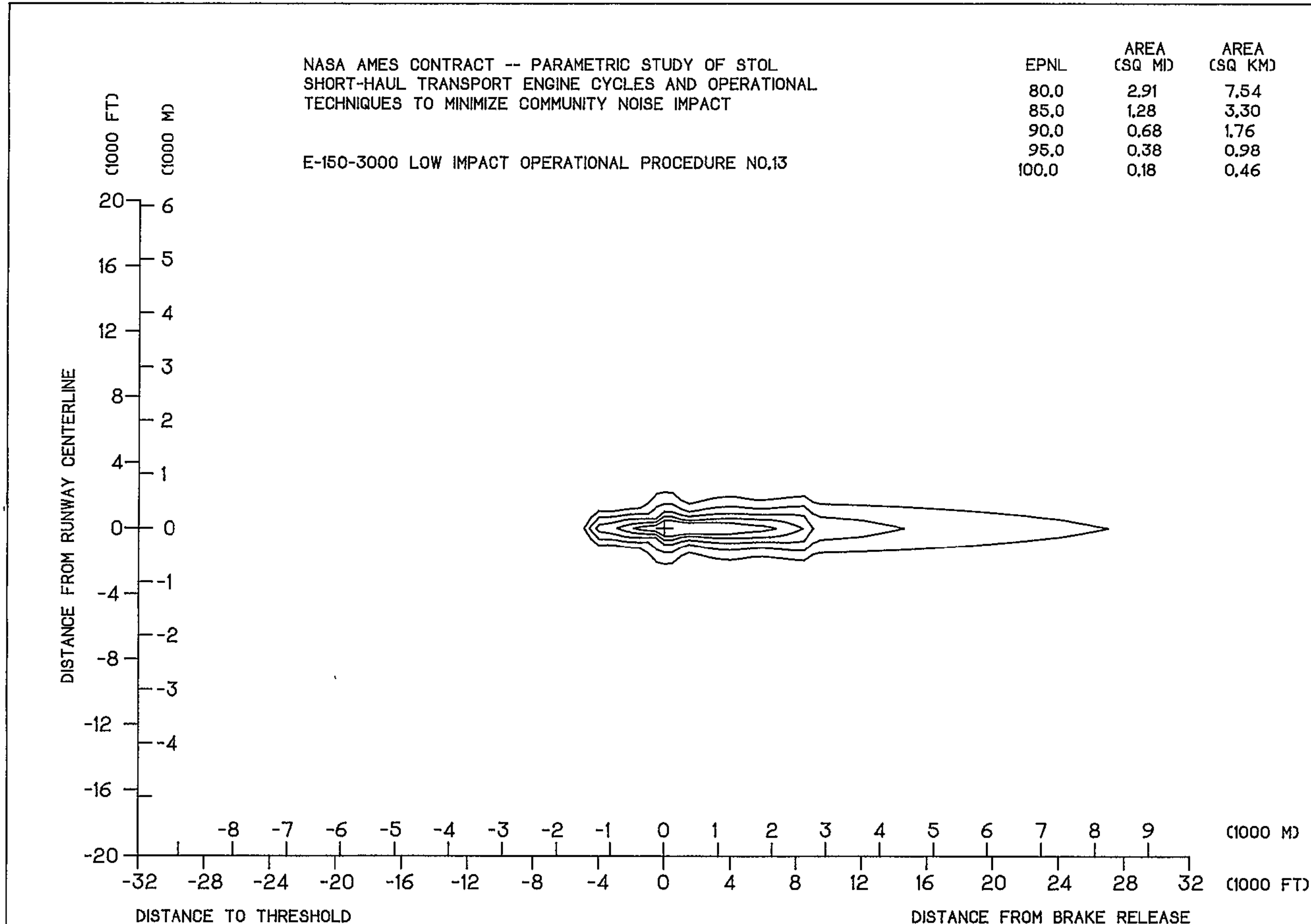

NASA AMES CONTRACT -- PARAMETRIC STUDY OF STOL
SHORT-HAUL TRANSPORT ENGINE CYCLES AND OPERATIONAL
TECHNIQUES TO MINIMIZE COMMUNITY NOISE IMPACT
E-150-3000 LOW IMPACT OPERATIONAL PROCEDURE NO.13
EPNL
AREA (SQ MI)
AREA (SQ KM)
80.0 2.91 7.54
85.0 1.28 3.30
90.0 0.68 1.76
95.0 0.38 0.98
100.0 0.18 0.46
(1000 FT)
(1000 M)
DISTANCE FROM RUNWAY CENTERLINE
DISTANCE TO THRESHOLD
DISTANCE FROM BRAKE RELEASE

FIGURE C-15.

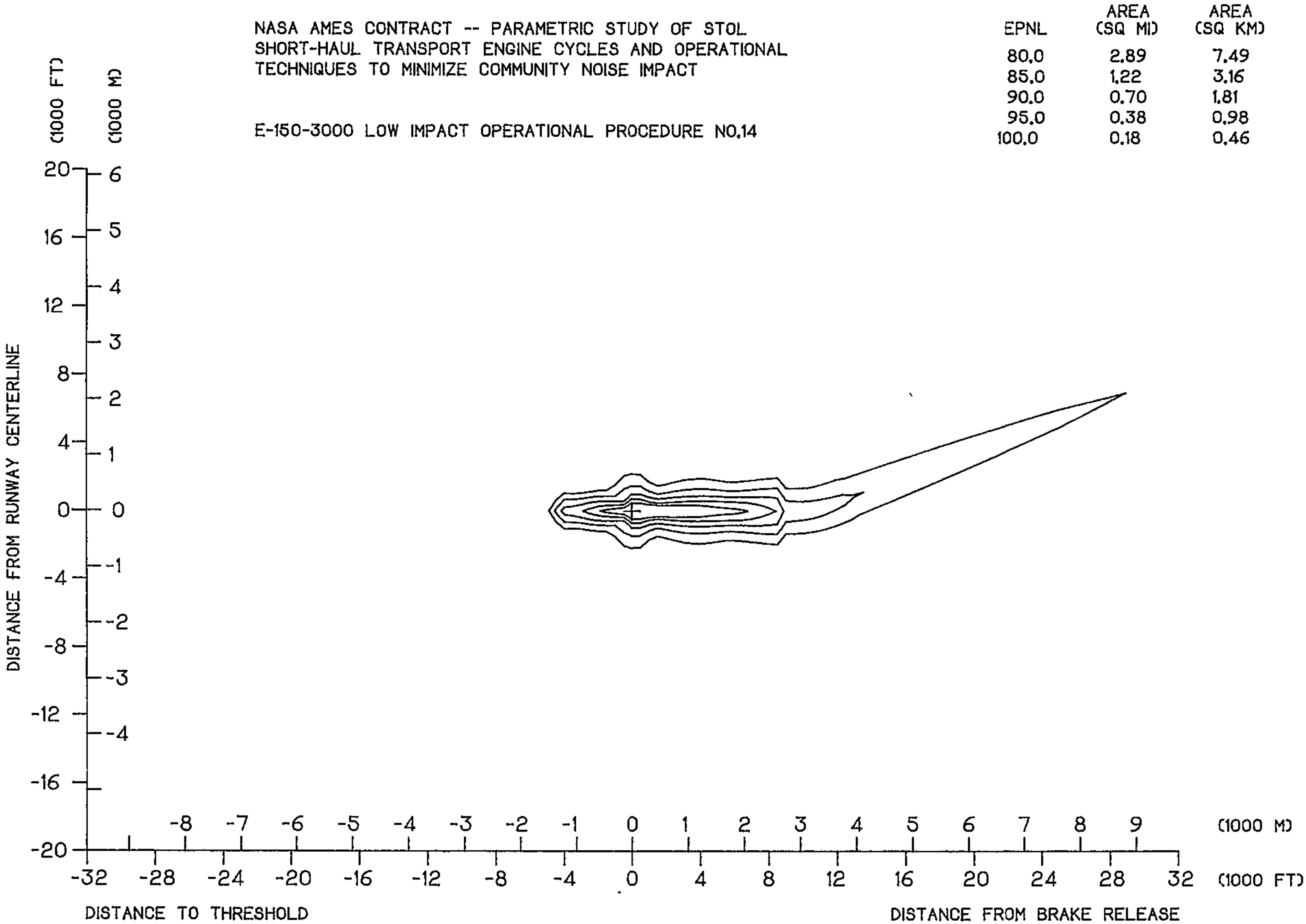

NASA AMES CONTRACT -- PARAMETRIC STUDY OF STOL
SHORT-HAUL TRANSPORT ENGINE CYCLES AND OPERATIONAL
TECHNIQUES TO MINIMIZE COMMUNITY NOISE IMPACT
E-150-3000 LOW IMPACT OPERATIONAL PROCEDURE NO.14
EPNL
AREA (SQ MI)
AREA (SQ KM)
80.0 2.89 7.49
85.0 1.22 3.16
90.0 0.70 1.81
95.0 0.38 0.98
100.0 0.18 0.46
(1000 FT)
(1000 M)
DISTANCE FROM RUNWAY CENTERLINE
20 16 12 8 4 0 -4 -8 -12 -16 -20
6 5 4 3 2 1 0 -1 -2 -3 -4
-8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 (1000 M)
-32 -28 -24 -20 -16 -12 -8 -4 0 4 8 12 16 20 24 28 32 (1000 FT)
DISTANCE TO THRESHOLD
DISTANCE FROM BRAKE RELEASE

FIGURE C-16.

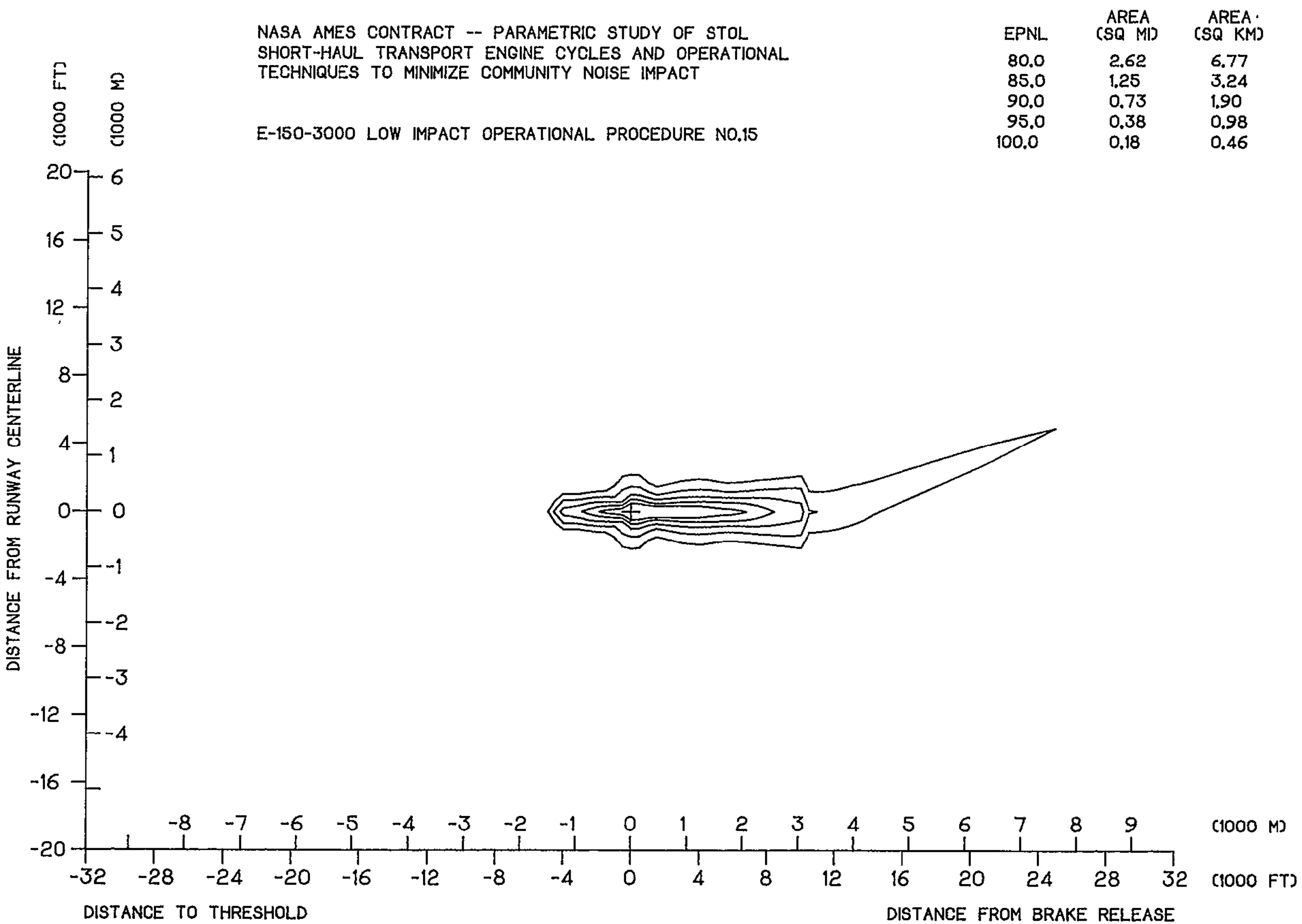

NASA AMES CONTRACT -- PARAMETRIC STUDY OF STOL
SHORT-HAUL TRANSPORT ENGINE CYCLES AND OPERATIONAL
TECHNIQUES TO MINIMIZE COMMUNITY NOISE IMPACT
E-150-3000 LOW IMPACT OPERATIONAL PROCEDURE NO.15
EPNL
AREA (SQ MI)
AREA (SQ KM)
80.0 2.62 6.77
85.0 1.25 3.24
90.0 0.73 1.90
95.0 0.38 0.98
100.0 0.18 0.46
(1000 FT)
(1000 M)
DISTANCE FROM RUNWAY CENTERLINE
20
16
12
8
4
0
-4
-8
-12
-16
-20
6
5
4
3
2
1
0
-1
-2
-3
-4
-8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9
(1000 M)
-32 -28 -24 -20 -16 -12 -8 -4 0 4 8 12 16 20 24 28 32
(1000 FT)
DISTANCE TO THRESHOLD
DISTANCE FROM BRAKE RELEASE

FIGURE C-17.

NASA AMES CONTRACT -- PARAMETRIC STUDY OF STOL SHORT-HAUL TRANSPORT ENGINE CYCLES AND OPERATIONAL TECHNIQUES TO MINIMIZE COMMUNITY NOISE IMPACT

E-150-3000 LOW IMPACT OPERATIONAL PROCEDURE NO.16

EPNL	AREA (SQ MI)	AREA (SQ KM)
80.0	2.56	6.63
85.0	1.51	3.92
90.0	0.76	1.97
95.0	0.38	0.98
100.0	0.18	0.46

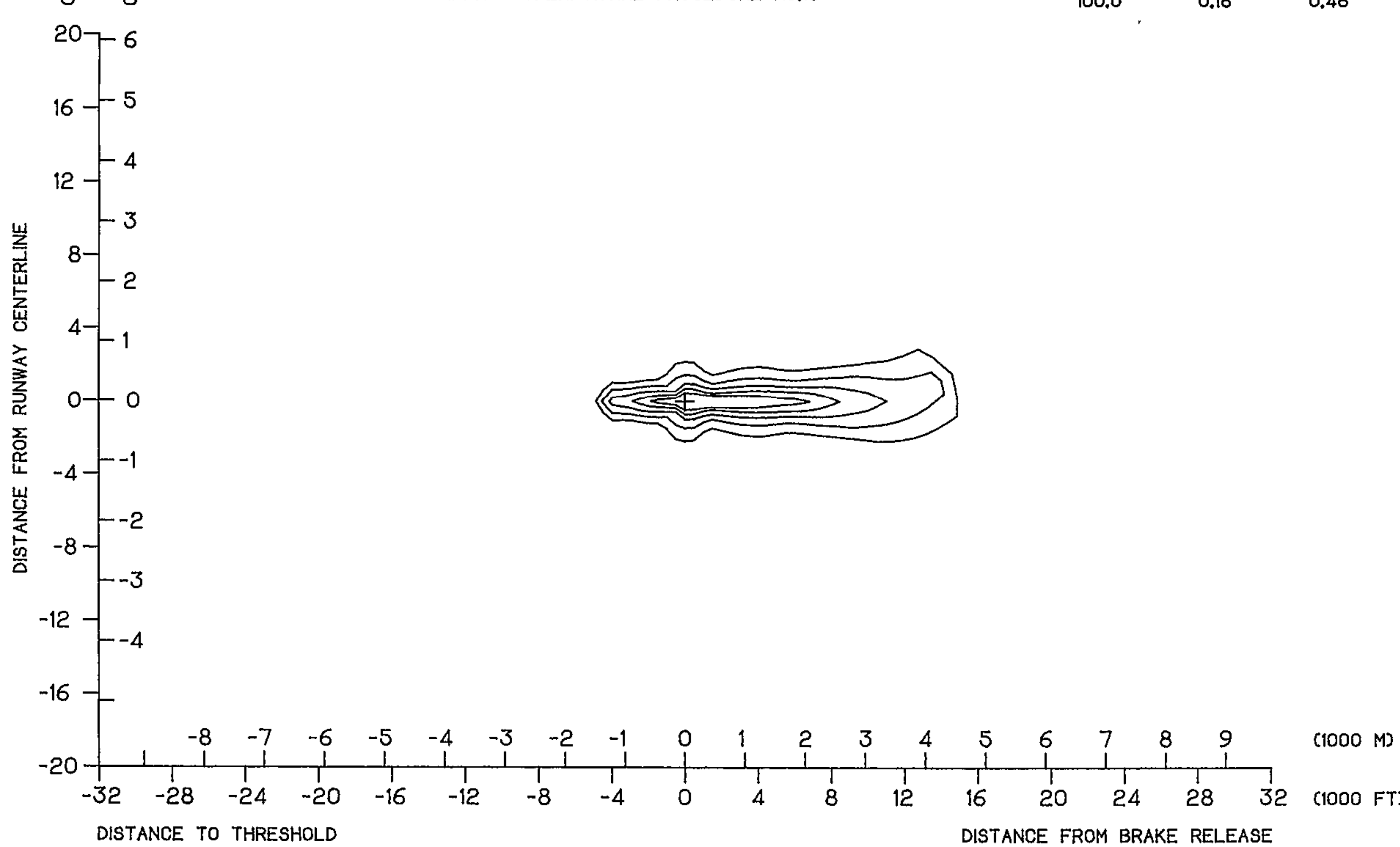
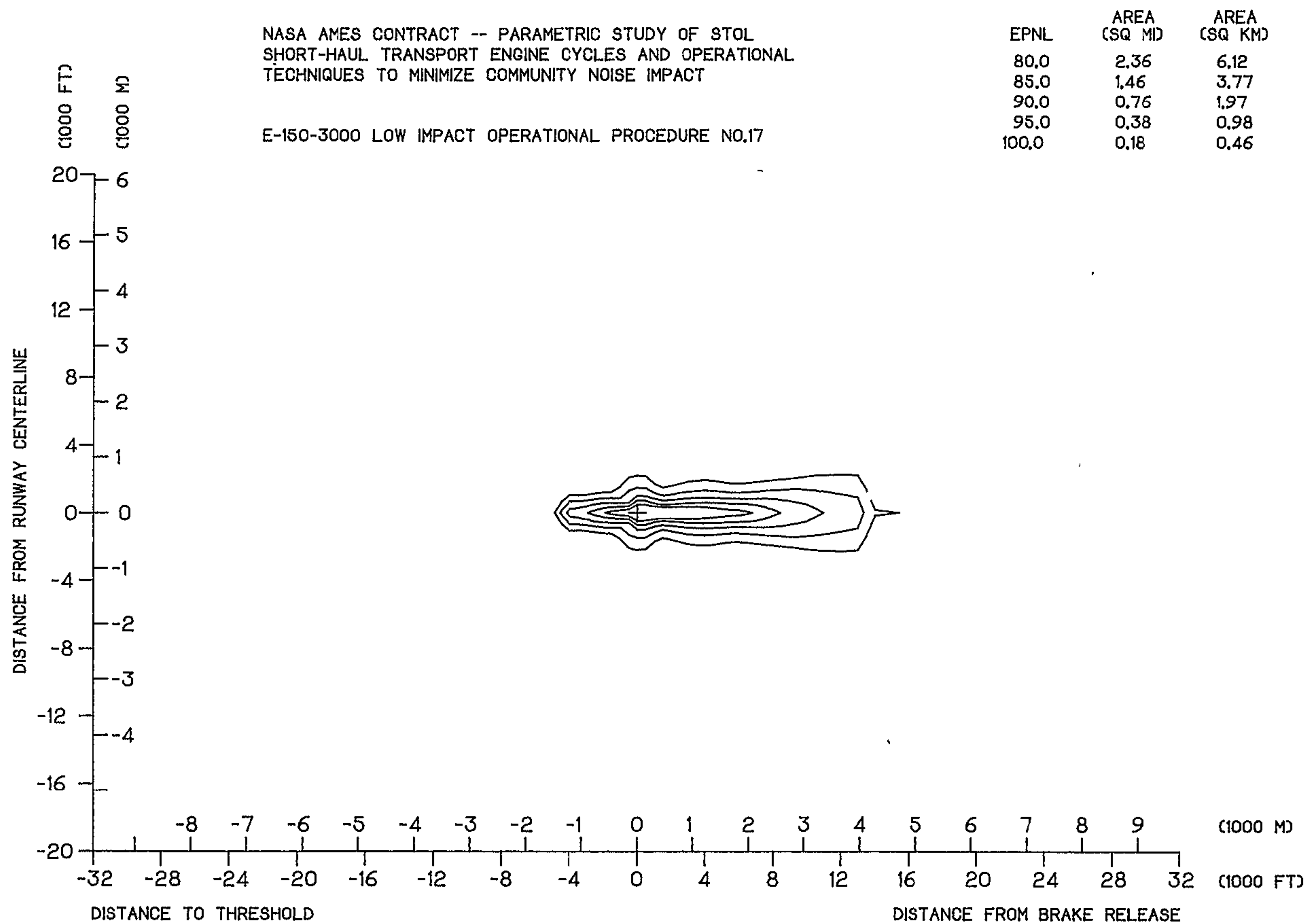


FIGURE C-18.



EPNL	AREA (SQ MI)	AREA (SQ KM)
80.0	2.36	6.12
85.0	1.46	3.77
90.0	0.76	1.97
95.0	0.38	0.98
100.0	0.18	0.46

FIGURE C-19.

NASA AMES CONTRACT -- PARAMETRIC STUDY OF STOL SHORT-HAUL TRANSPORT ENGINE CYCLES AND OPERATIONAL TECHNIQUES TO MINIMIZE COMMUNITY NOISE IMPACT

E-150-3000 LOW IMPACT OPERATIONAL PROCEDURE NO.18

EPNL	AREA (SQ MI)	AREA (SQ KM)
80.0	2.73	7.08
85.0	1.55	4.02
90.0	0.76	1.97
95.0	0.38	0.98
100.0	0.18	0.46

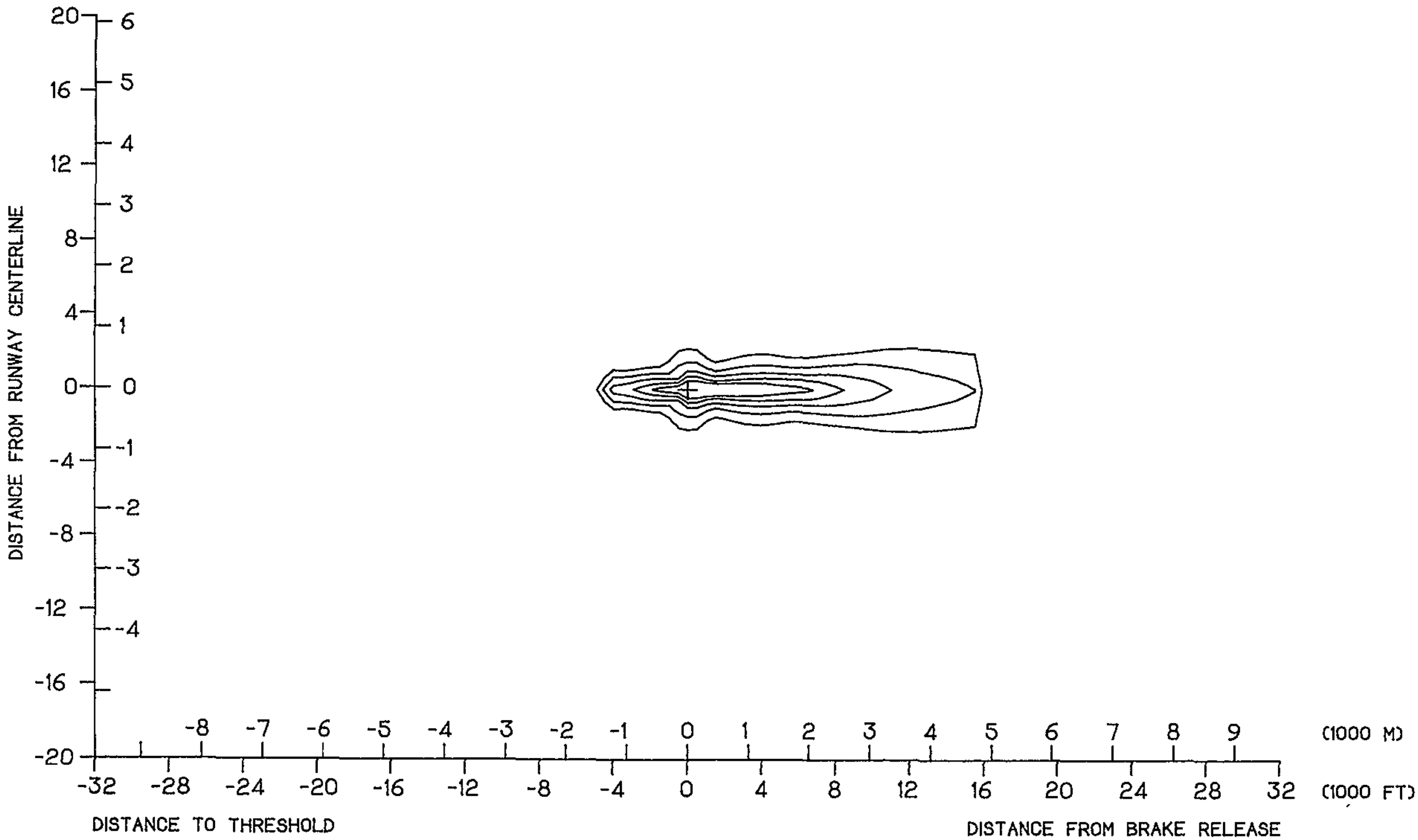


FIGURE C-20.

NASA AMES CONTRACT -- PARAMETRIC STUDY OF STOL SHORT-HAUL TRANSPORT ENGINE CYCLES AND OPERATIONAL TECHNIQUES TO MINIMIZE COMMUNITY NOISE IMPACT

E-150-3000 LOW IMPACT OPERATIONAL PROCEDURE NO. 19

EPNL	AREA (SQ MI)	AREA (SQ KM)
80.0	3.21	8.32
85.0	1.33	3.44
90.0	0.62	1.60
95.0	0.36	0.93
100.0	0.18	0.46

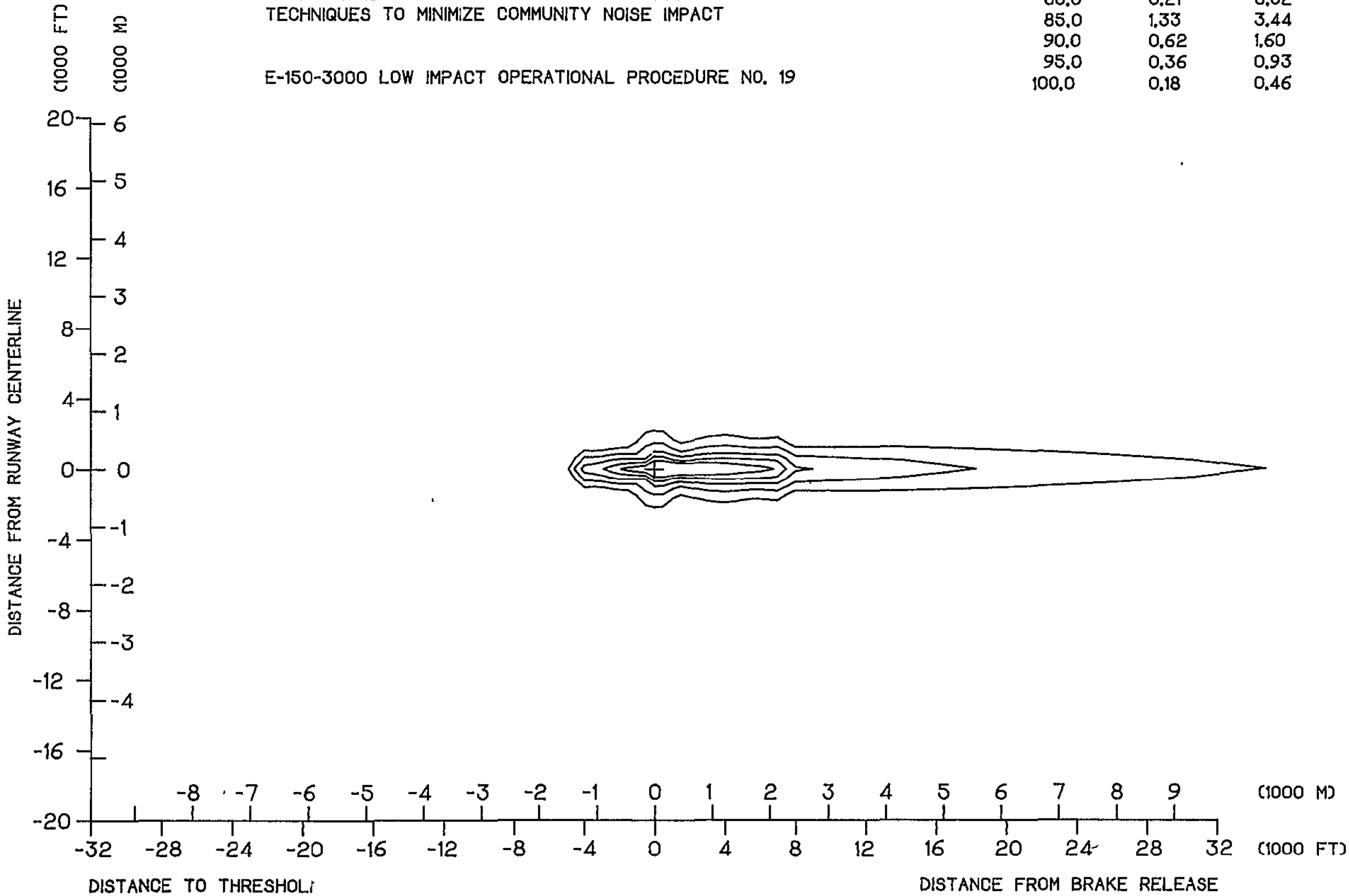


FIGURE C-21.

NASA AMES CONTRACT -- PARAMETRIC STUDY OF STOL SHORT-HAUL TRANSPORT ENGINE CYCLES AND OPERATIONAL TECHNIQUES TO MINIMIZE COMMUNITY NOISE IMPACT

E-150-3000 LOW IMPACT OPERATIONAL PROCEDURE NO. 20

EPNL	AREA (SQ MI)	AREA (SQ KM)
80.0	3.12	8.08
85.0	1.45	3.75
90.0	0.62	1.60
95.0	0.36	0.93
100.0	0.18	0.46

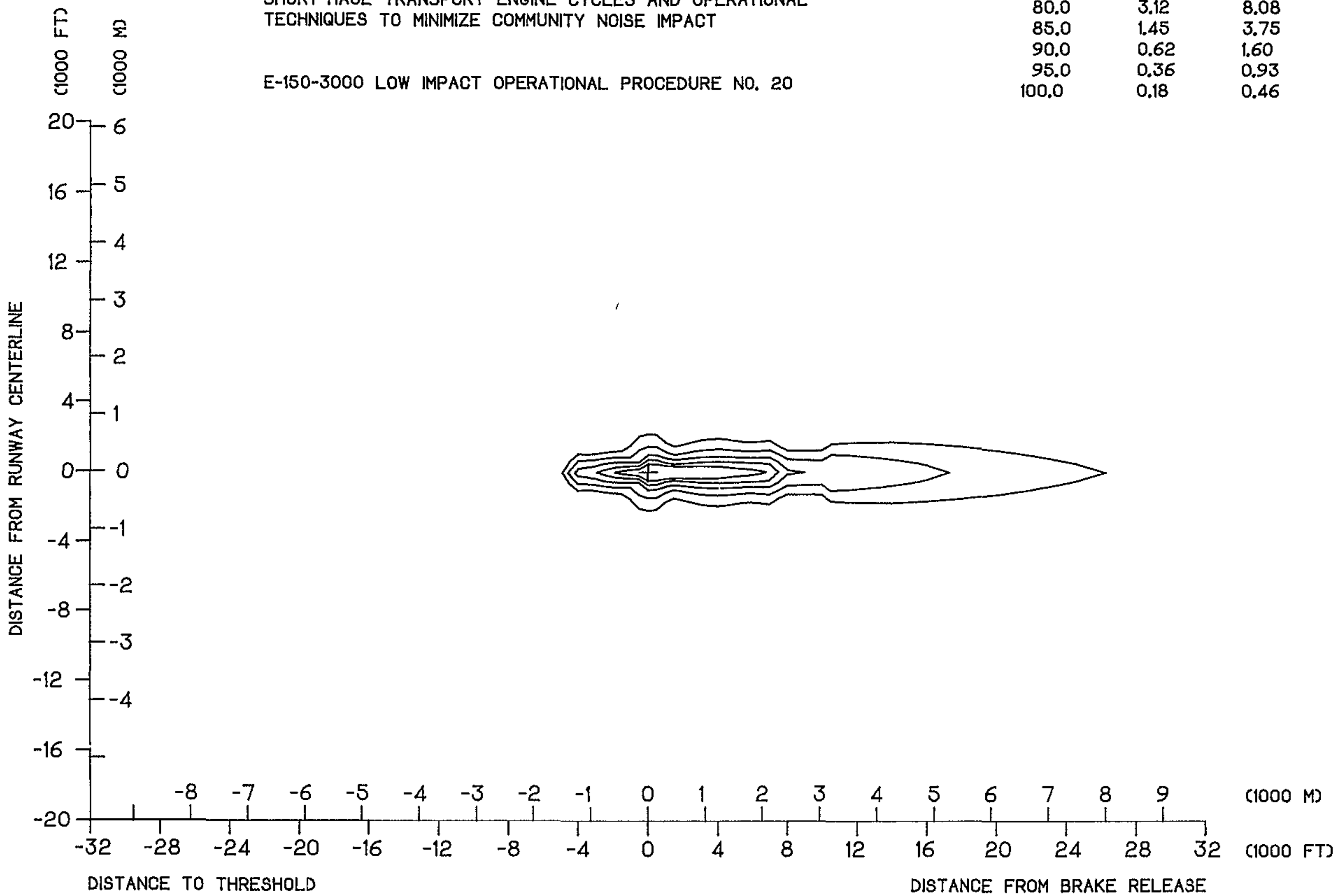
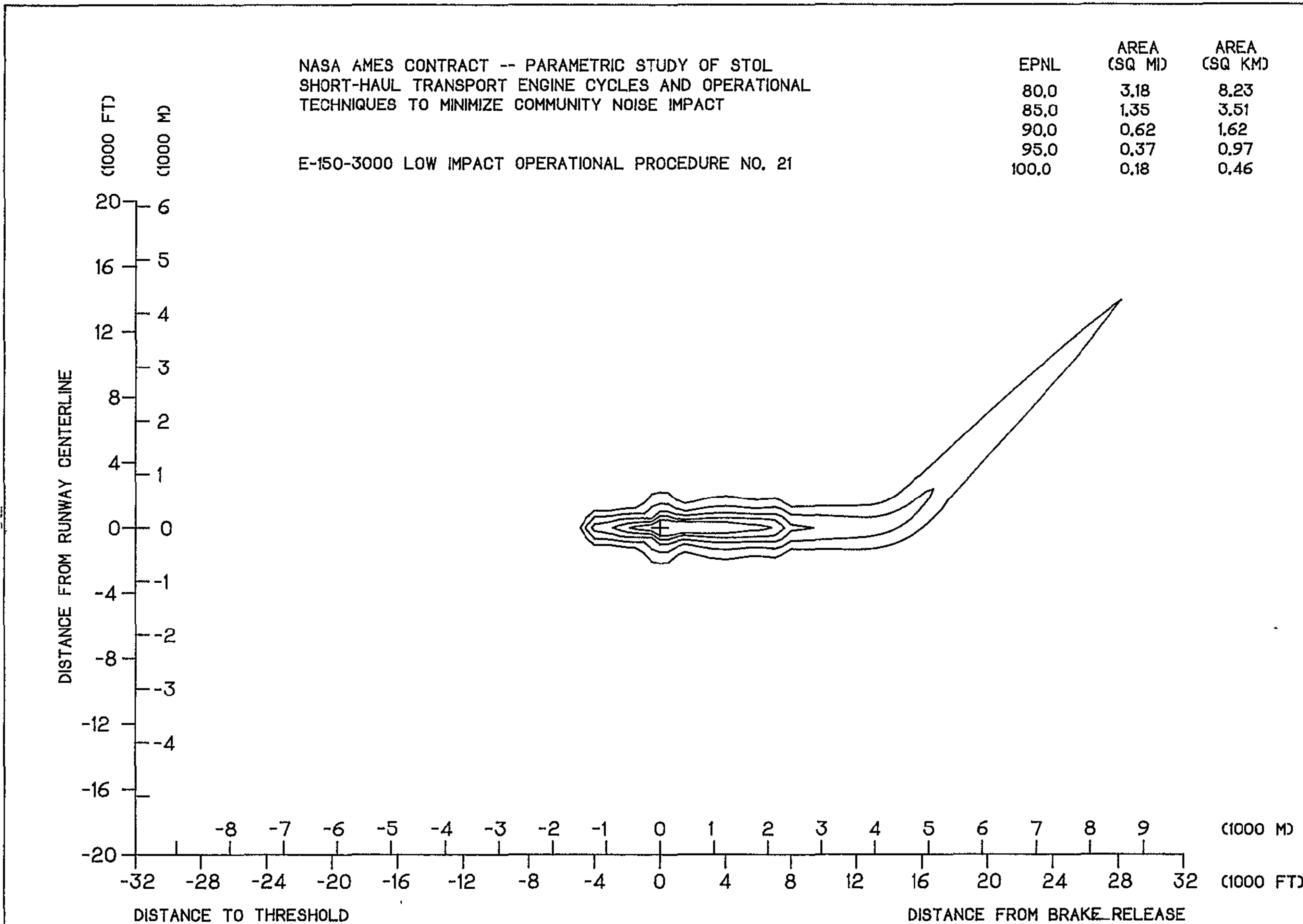


FIGURE C-22.



NASA AMES CONTRACT -- PARAMETRIC STUDY OF STOL
SHORT-HAUL TRANSPORT ENGINE CYCLES AND OPERATIONAL
TECHNIQUES TO MINIMIZE COMMUNITY NOISE IMPACT
E-150-3000 LOW IMPACT OPERATIONAL PROCEDURE NO. 21
EPNL
AREA (SQ MI)
AREA (SQ KM)
80.0 3.18 8.23
85.0 1.35 3.51
90.0 0.62 1.62
95.0 0.37 0.97
100.0 0.18 0.46
(1000 FT)
(1000 M)
DISTANCE FROM RUNWAY CENTERLINE
20 16 12 8 4 0 -4 -8 -12 -16 -20
6 5 4 3 2 1 0 -1 -2 -3 -4
-8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 (1000 M)
-32 -28 -24 -20 -16 -12 -8 -4 0 4 8 12 16 20 24 28 32 (1000 FT)
DISTANCE TO THRESHOLD
DISTANCE FROM BRAKE RELEASE

FIGURE C-23.

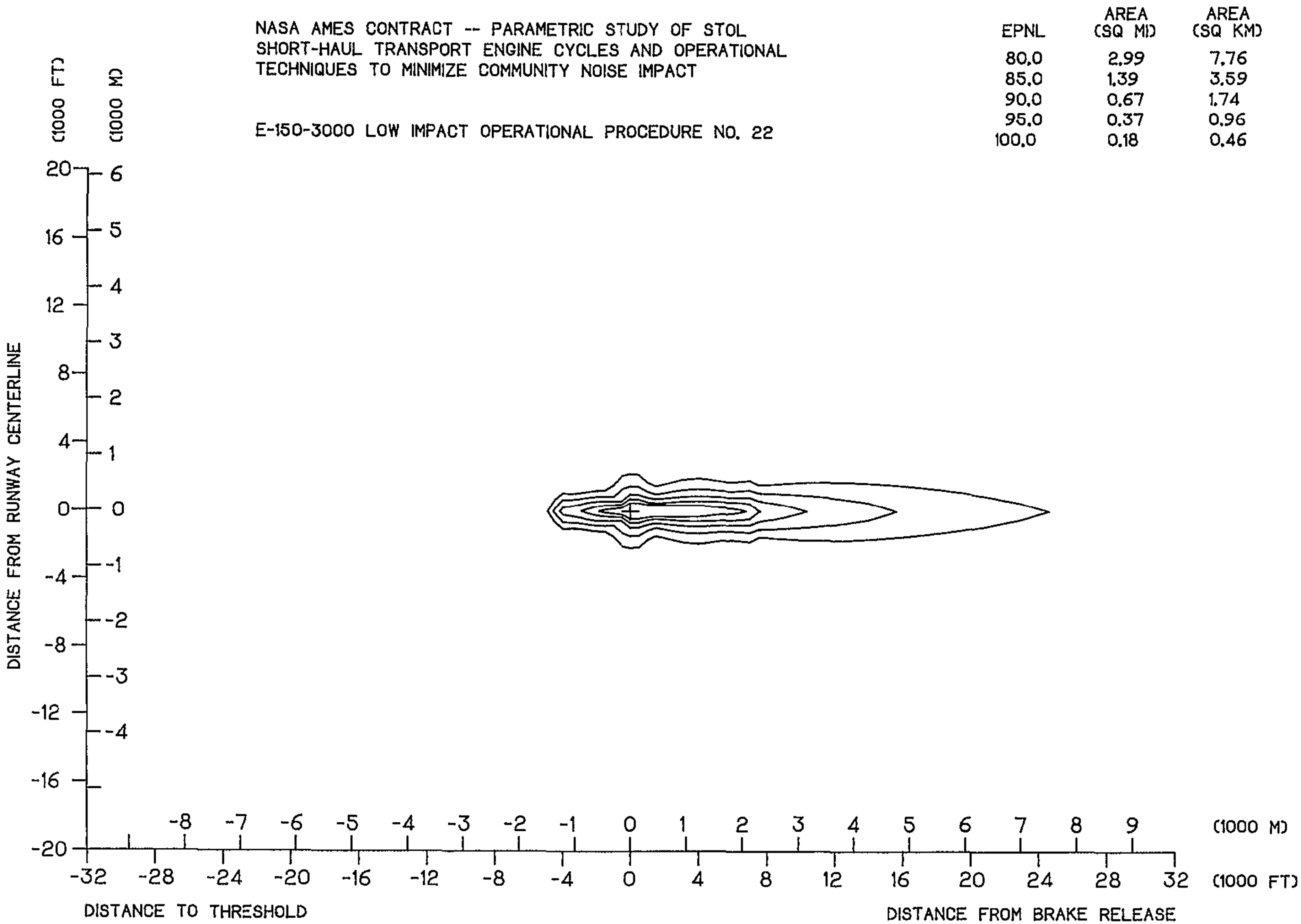

NASA AMES CONTRACT -- PARAMETRIC STUDY OF STOL
SHORT-HAUL TRANSPORT ENGINE CYCLES AND OPERATIONAL
TECHNIQUES TO MINIMIZE COMMUNITY NOISE IMPACT
E-150-3000 LOW IMPACT OPERATIONAL PROCEDURE NO. 22
EPNL | AREA (SQ MI) | AREA (SQ KM)
80.0 | 2.99 | 7.76
85.0 | 1.39 | 3.59
90.0 | 0.67 | 1.74
95.0 | 0.37 | 0.96
100.0 | 0.18 | 0.46
(1000 FT)
(1000 M)
DISTANCE FROM RUNWAY CENTERLINE
20
16
12
8
4
0
-4
-8
-12
-16
-20
6
5
4
3
2
1
0
-1
-2
-3
-4
-8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 (1000 M)
-32 -28 -24 -20 -16 -12 -8 -4 0 4 8 12 16 20 24 28 32 (1000 FT)
DISTANCE TO THRESHOLD
DISTANCE FROM BRAKE RELEASE

FIGURE C-24.

NASA AMES CONTRACT -- PARAMETRIC STUDY OF STOL SHORT-HAUL TRANSPORT ENGINE CYCLES AND OPERATIONAL TECHNIQUES TO MINIMIZE COMMUNITY NOISE IMPACT

E-150-3000 LOW IMPACT OPERATIONAL PROCEDURE NO. 23

EPNL	AREA (SQ MI)	AREA (SQ KM)
80.0	2.74	7.09
85.0	1.25	3.23
90.0	0.73	1.89
95.0	0.38	0.98
100.0	0.18	0.46

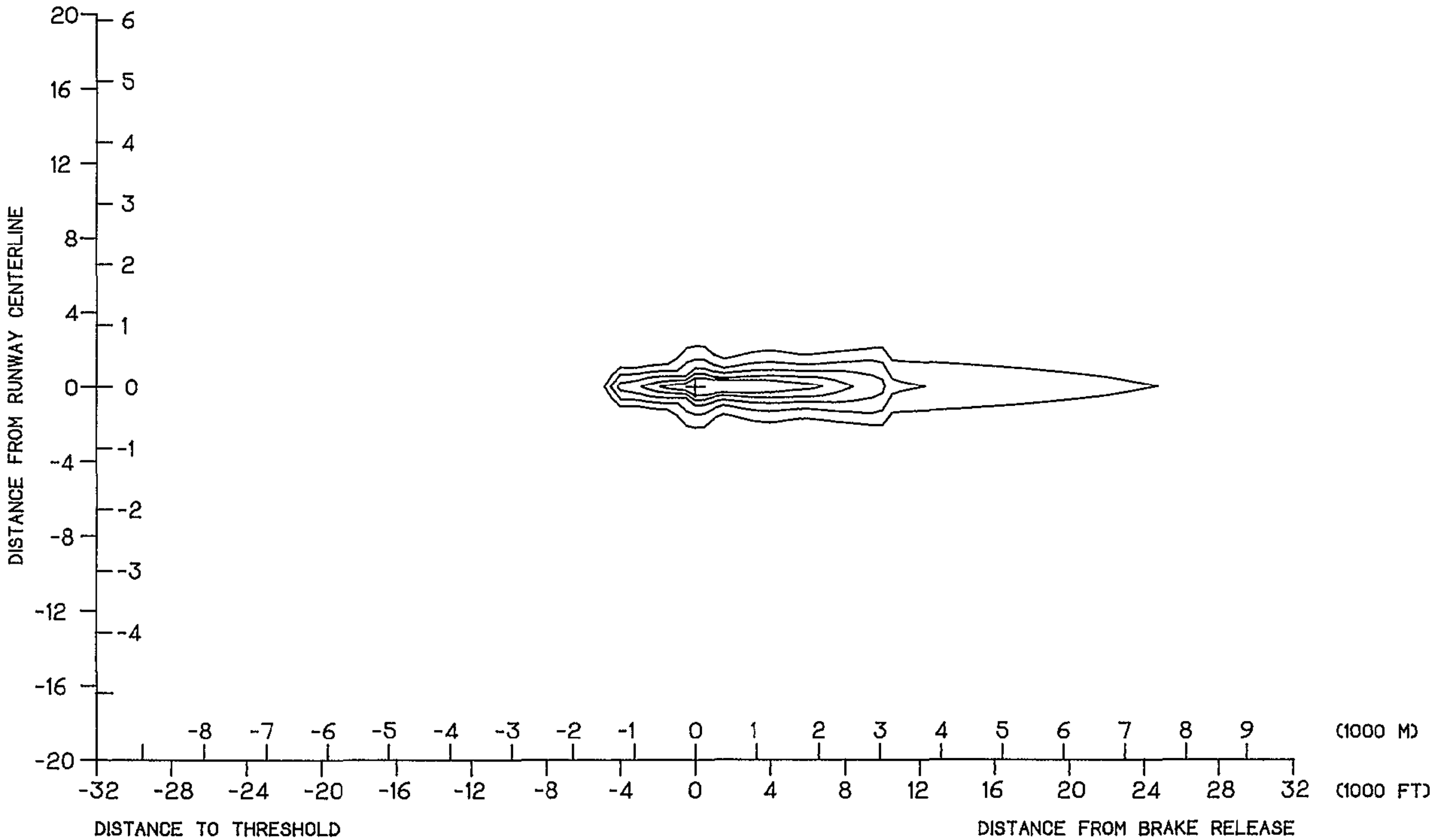


FIGURE C-25.

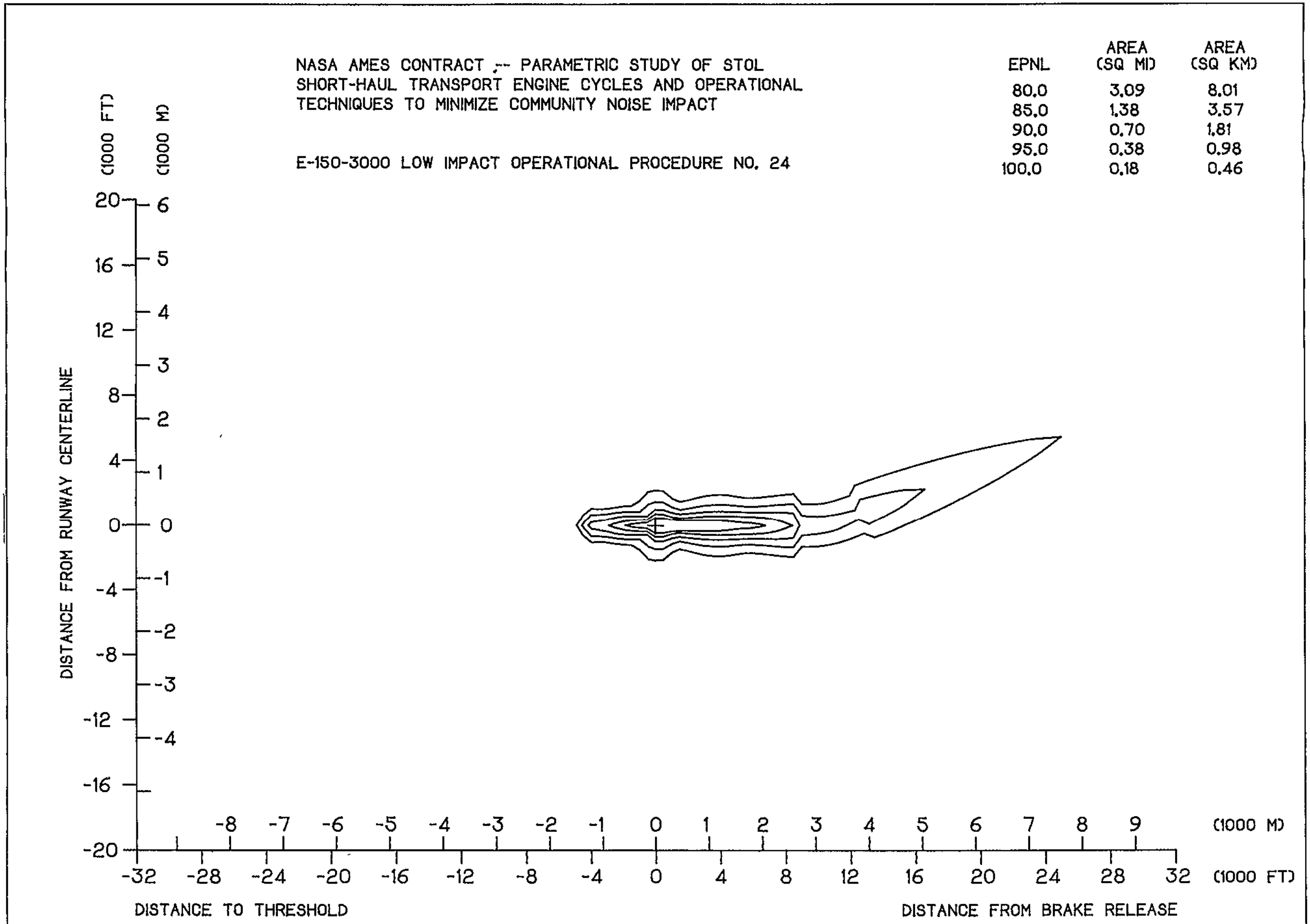

NASA AMES CONTRACT -- PARAMETRIC STUDY OF STOL
SHORT-HAUL TRANSPORT ENGINE CYCLES AND OPERATIONAL
TECHNIQUES TO MINIMIZE COMMUNITY NOISE IMPACT
E-150-3000 LOW IMPACT OPERATIONAL PROCEDURE NO. 24
EPNL
AREA (SQ MI)
AREA (SQ KM)
80.0 3.09 8.01
85.0 1.38 3.57
90.0 0.70 1.81
95.0 0.38 0.98
100.0 0.18 0.46
(1000 FT)
(1000 M)
DISTANCE FROM RUNWAY CENTERLINE
(1000 M)
(1000 FT)
DISTANCE TO THRESHOLD
DISTANCE FROM BRAKE RELEASE

FIGURE C-26.

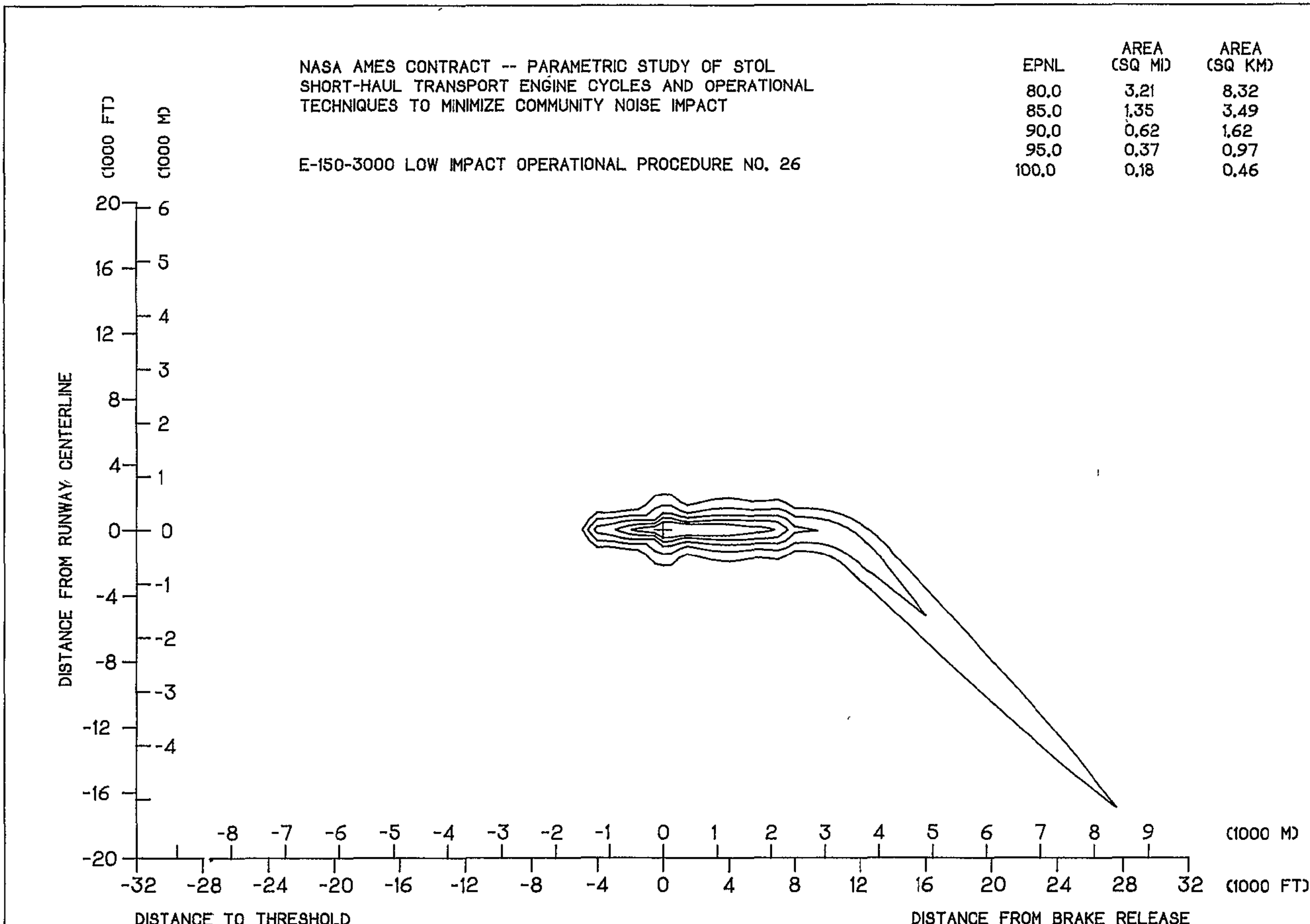

NASA AMES CONTRACT -- PARAMETRIC STUDY OF STOL
SHORT-HAUL TRANSPORT ENGINE CYCLES AND OPERATIONAL
TECHNIQUES TO MINIMIZE COMMUNITY NOISE IMPACT
E-150-3000 LOW IMPACT OPERATIONAL PROCEDURE NO. 26
EPNL
AREA (SQ MI)
AREA (SQ KM)
80.0 3.21 8.32
85.0 1.35 3.49
90.0 0.62 1.62
95.0 0.37 0.97
100.0 0.18 0.46
(1000 FT)
(1000 M)
DISTANCE FROM RUNWAY CENTERLINE
DISTANCE TO THRESHOLD
DISTANCE FROM BRAKE RELEASE

FIGURE C-27.

NASA AMES CONTRACT -- PARAMETRIC STUDY OF STOL
SHORT-HAUL TRANSPORT ENGINE CYCLES AND OPERATIONAL
TECHNIQUES TO MINIMIZE COMMUNITY NOISE IMPACT

E-150-3000 LOW IMPACT OPERATIONAL PROCEDURE NO. 27

EPNL	AREA (SQ MI)	AREA (SQ KM)
80.0	3.19	8.27
85.0	1.34	3.48
90.0	0.62	1.62
95.0	0.37	0.97
100.0	0.18	0.46

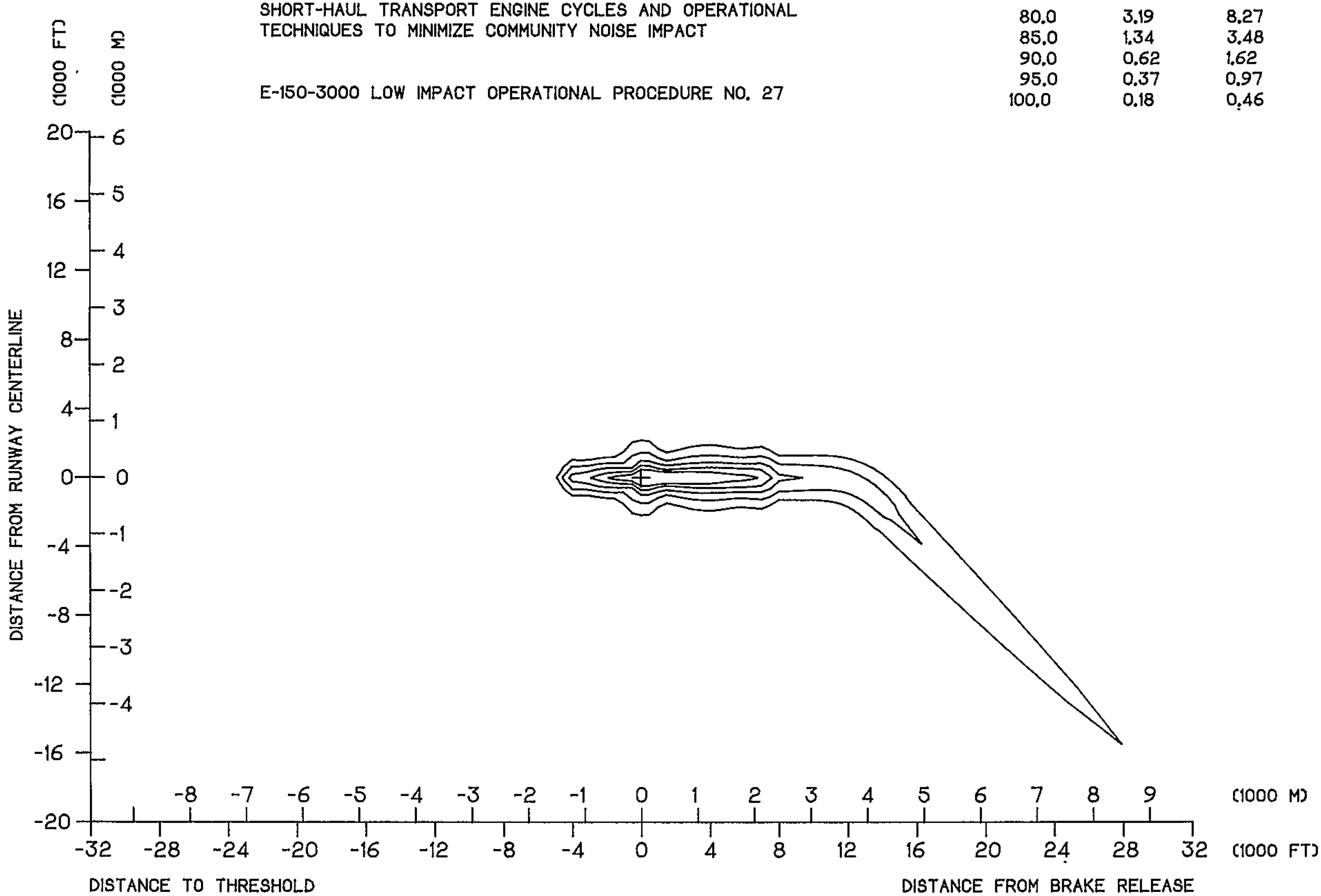


FIGURE C-28.

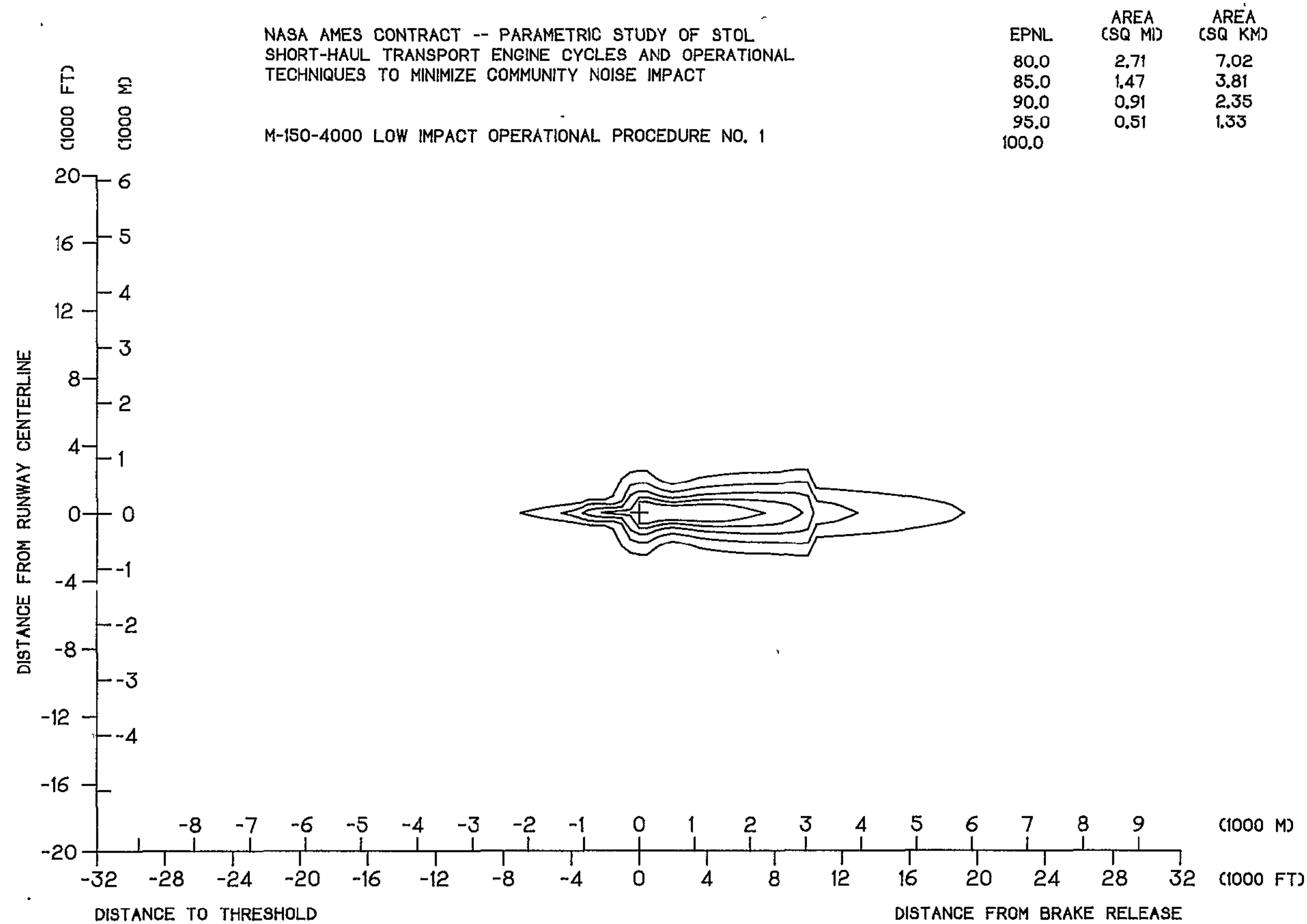

NASA AMES CONTRACT -- PARAMETRIC STUDY OF STOL
SHORT-HAUL TRANSPORT ENGINE CYCLES AND OPERATIONAL
TECHNIQUES TO MINIMIZE COMMUNITY NOISE IMPACT
M-150-4000 LOW IMPACT OPERATIONAL PROCEDURE NO. 1
EPNL
AREA (SQ MI)
AREA (SQ KM)
80.0 2.71 7.02
85.0 1.47 3.81
90.0 0.91 2.35
95.0 0.51 1.33
100.0
(1000 FT)
(1000 M)
DISTANCE FROM RUNWAY CENTERLINE
20 16 12 8 4 0 -4 -8 -12 -16 -20
6 5 4 3 2 1 0 -1 -2 -3 -4
-8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 (1000 M)
-32 -28 -24 -20 -16 -12 -8 -4 0 4 8 12 16 20 24 28 32 (1000 FT)
DISTANCE TO THRESHOLD
DISTANCE FROM BRAKE RELEASE

FIGURE C-29.

NASA AMES CONTRACT -- PARAMETRIC STUDY OF STOL SHORT-HAUL TRANSPORT ENGINE CYCLES AND OPERATIONAL TECHNIQUES TO MINIMIZE COMMUNITY NOISE IMPACT

M-150-4000 LOW IMPACT OPERATIONAL PROCEDURE NO. 2

EPNL	AREA (SQ MI)	AREA (SQ KM)
80.0	2.85	7.39
85.0	1.51	3.92
90.0	0.82	2.12
95.0	0.42	1.09
100.0	0.26	0.68

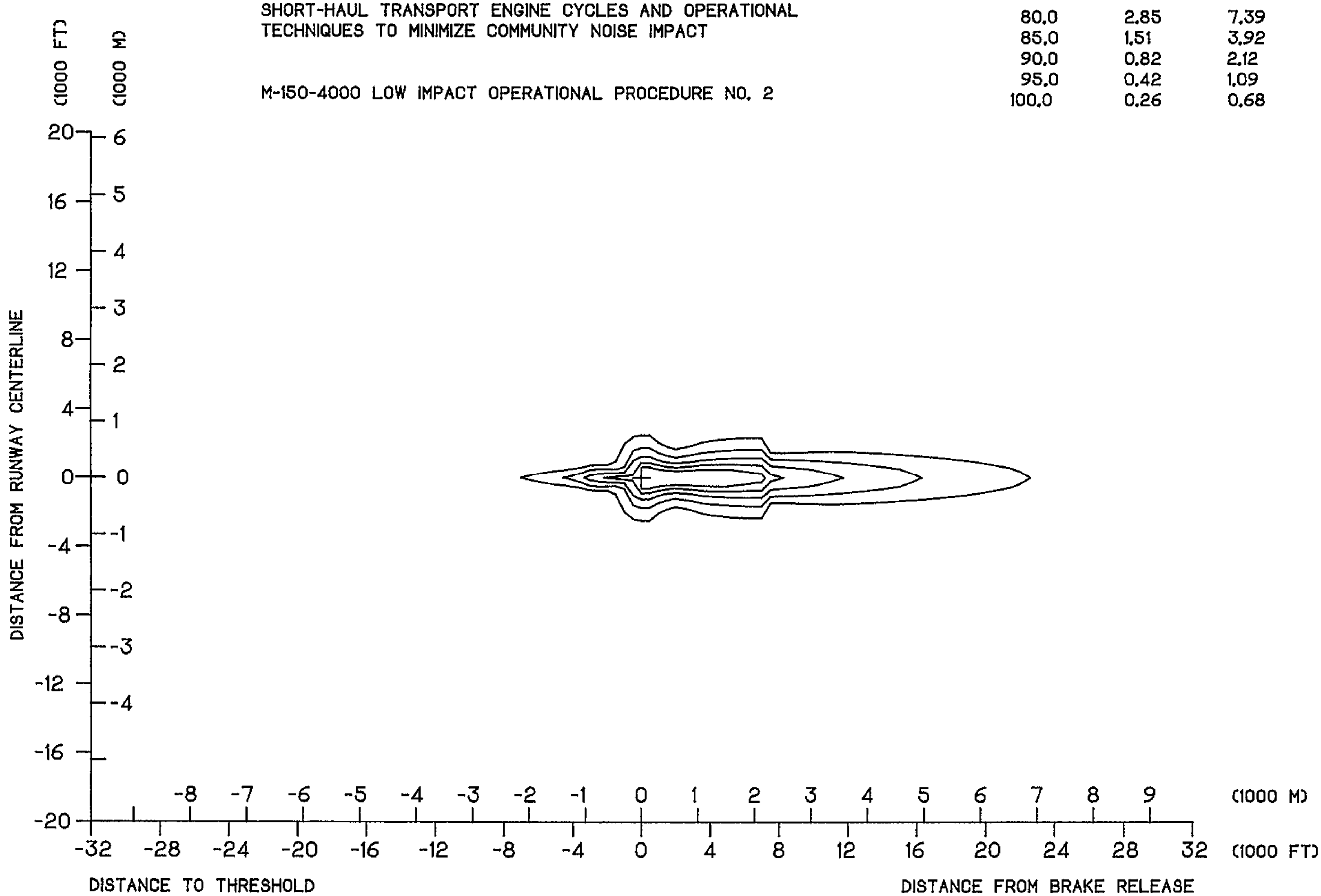


FIGURE C-30.

NASA AMES CONTRACT -- PARAMETRIC STUDY OF STOL SHORT-HAUL TRANSPORT ENGINE CYCLES AND OPERATIONAL TECHNIQUES TO MINIMIZE COMMUNITY NOISE IMPACT

M-150-4000 LOW IMPACT OPERATIONAL PROCEDURE NO. 3

EPNL	AREA (SQ MI)	AREA (SQ KM)
80.0	2.78	7.19
85.0	1.46	3.77
90.0	0.83	2.14
95.0	0.50	1.30
100.0	0.28	0.71

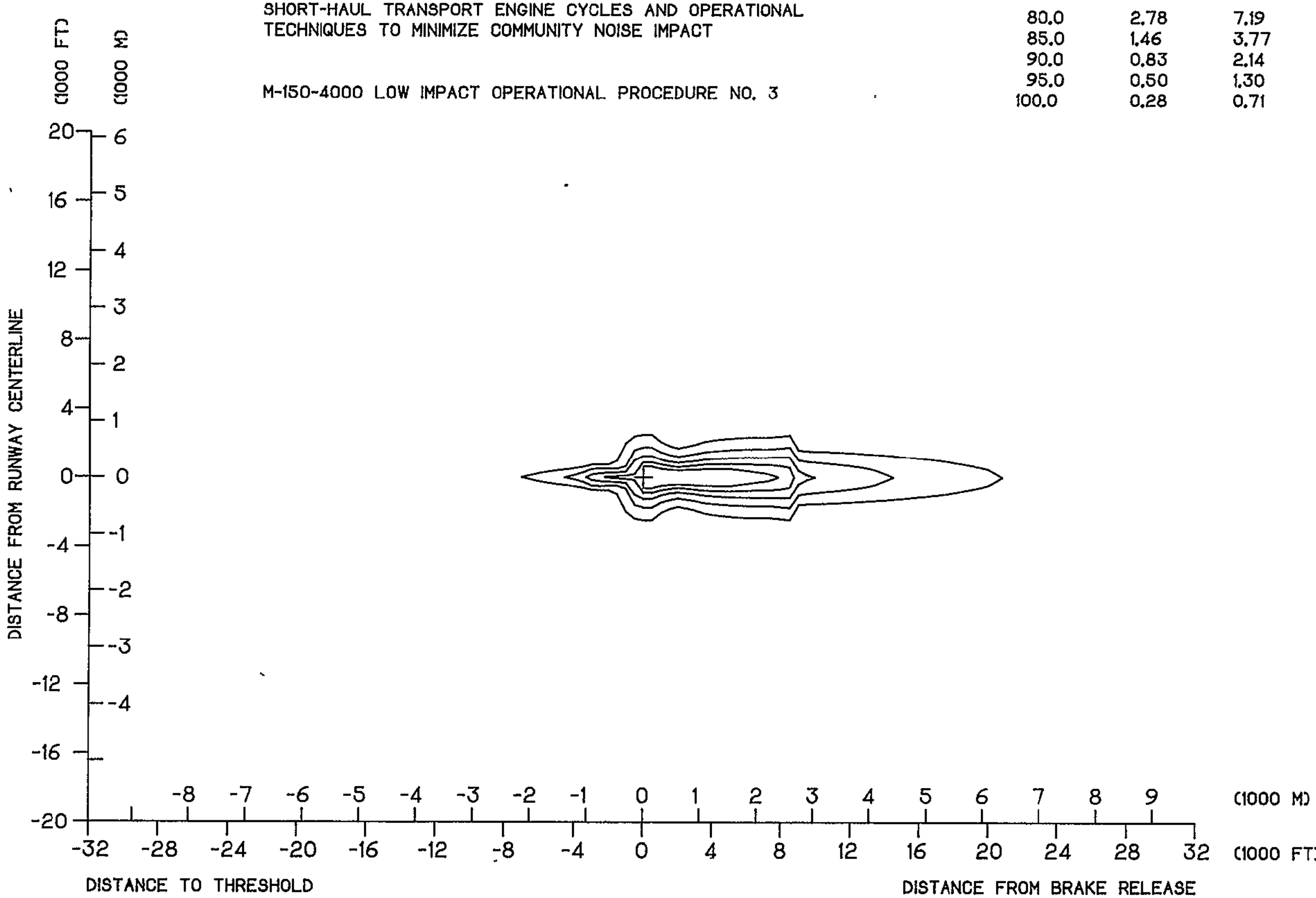


FIGURE C-31.

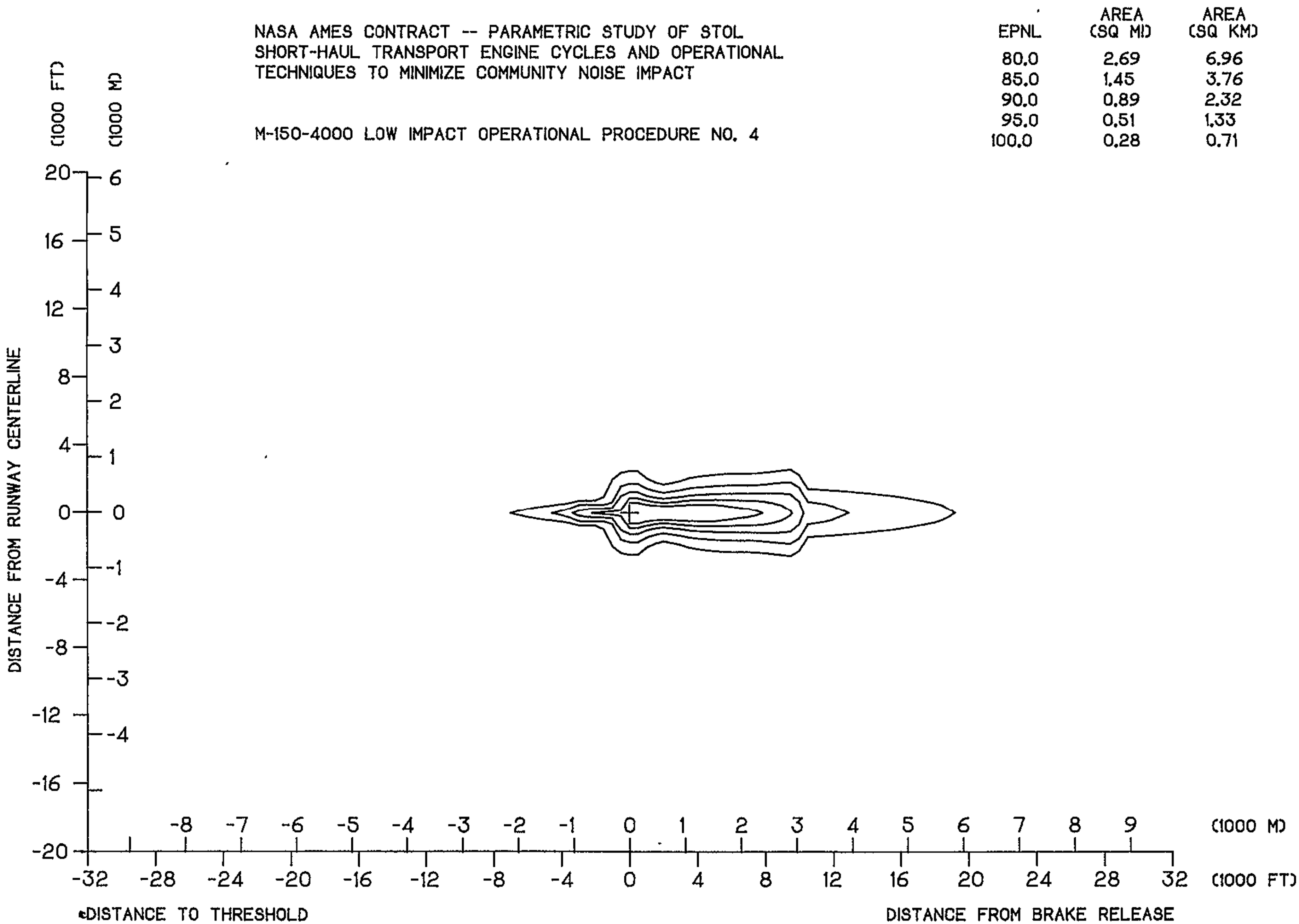

NASA AMES CONTRACT -- PARAMETRIC STUDY OF STOL
SHORT-HAUL TRANSPORT ENGINE CYCLES AND OPERATIONAL
TECHNIQUES TO MINIMIZE COMMUNITY NOISE IMPACT
M-150-4000 LOW IMPACT OPERATIONAL PROCEDURE NO. 4
EPNL
AREA (SQ MI)
AREA (SQ KM)
80.0 2.69 6.96
85.0 1.45 3.76
90.0 0.89 2.32
95.0 0.51 1.33
100.0 0.28 0.71
(1000 FT)
(1000 M)
DISTANCE FROM RUNWAY CENTERLINE
(1000 M)
(1000 FT)
DISTANCE TO THRESHOLD
DISTANCE FROM BRAKE RELEASE

FIGURE C-32.

NASA AMES CONTRACT -- PARAMETRIC STUDY OF STOL SHORT-HAUL TRANSPORT ENGINE CYCLES AND OPERATIONAL TECHNIQUES TO MINIMIZE COMMUNITY NOISE IMPACT

M-150-4000 LOW IMPACT OPERATIONAL PROCEDURE NO. 5

EPNL	AREA (SQ MI)	AREA (SQ KM)
80.0	2.72	7.04
85.0	1.48	3.82
90.0	0.91	2.36
95.0	0.51	1.32
100.0	0.25	0.65

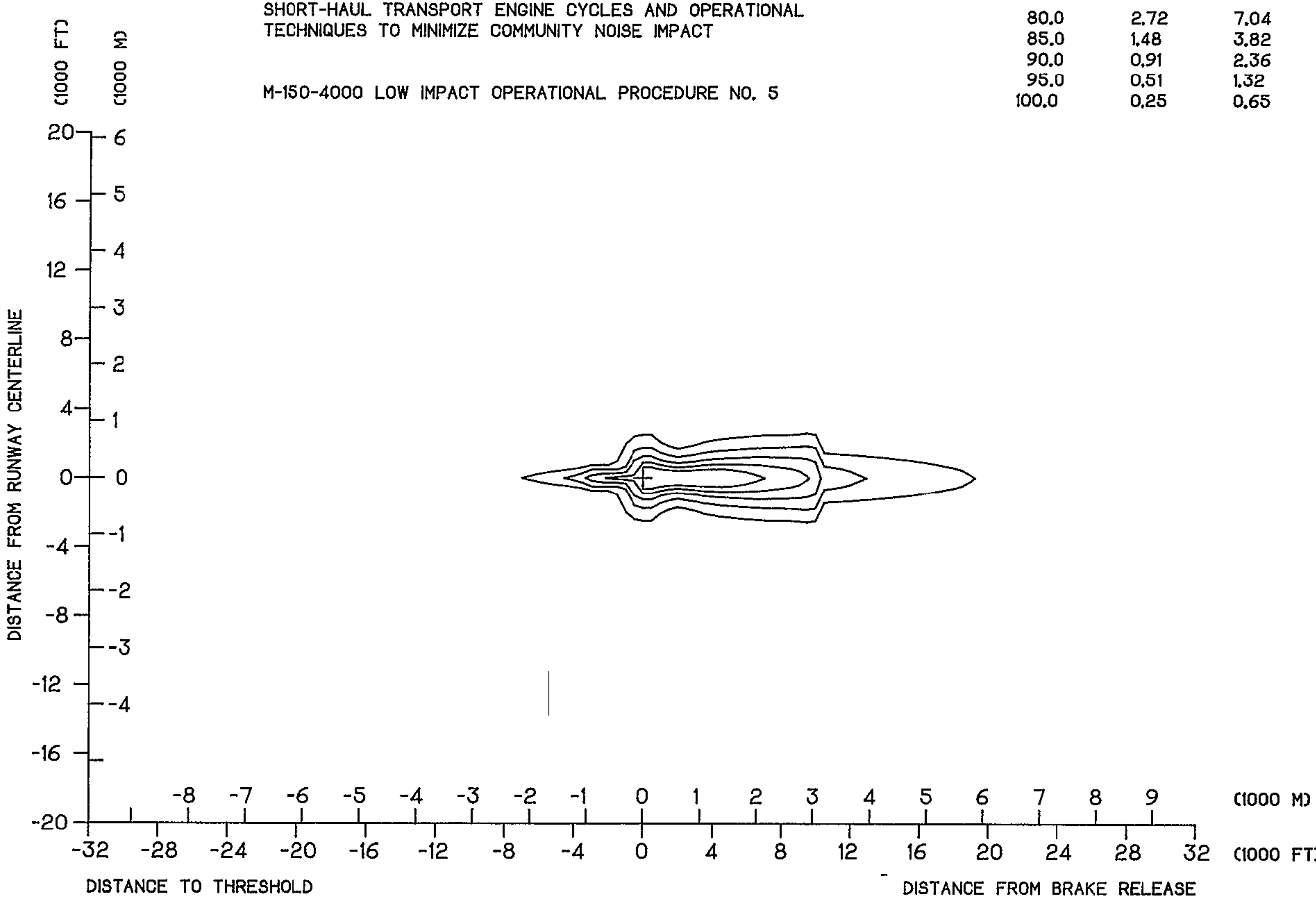


FIGURE C-33.

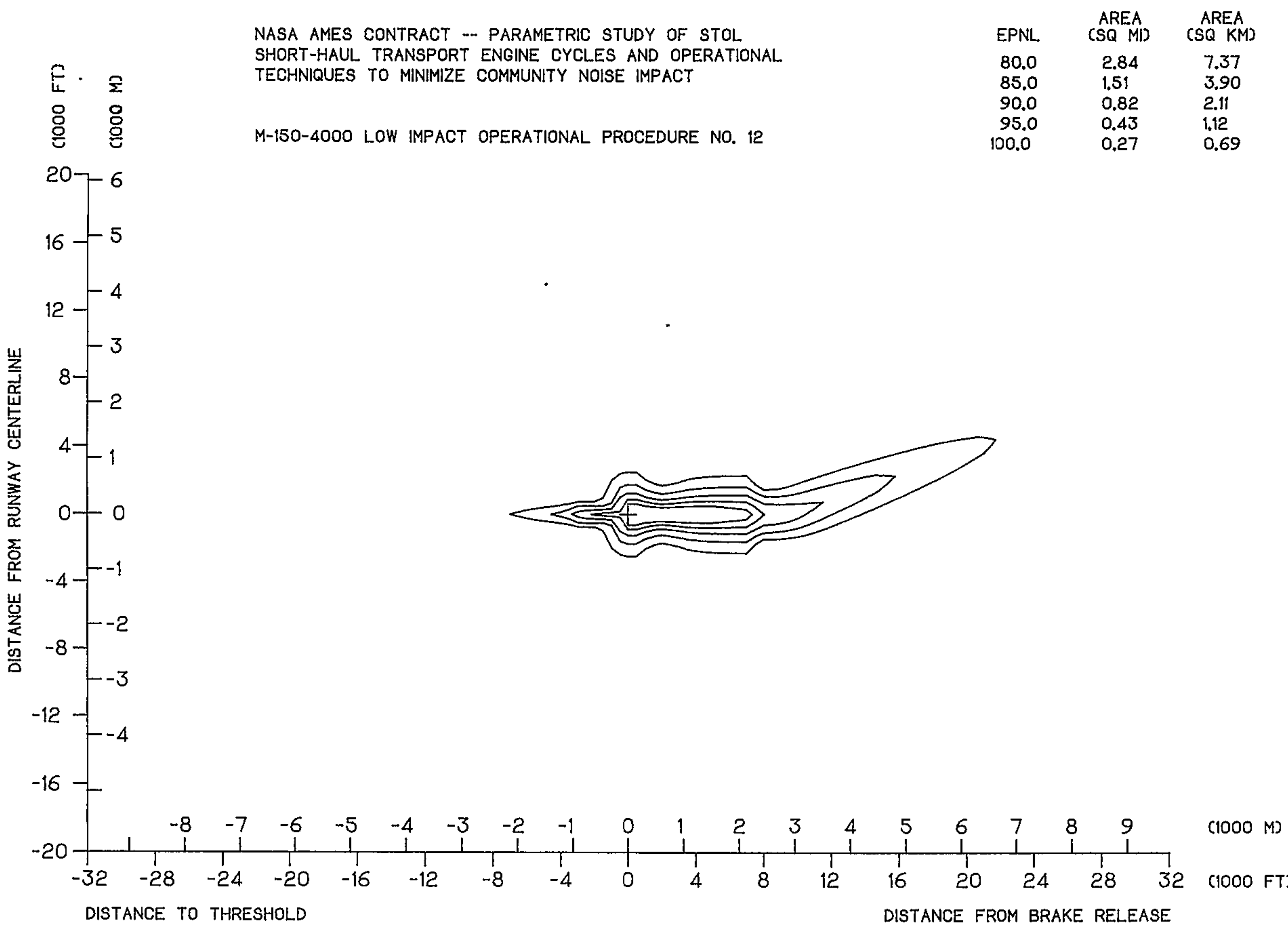
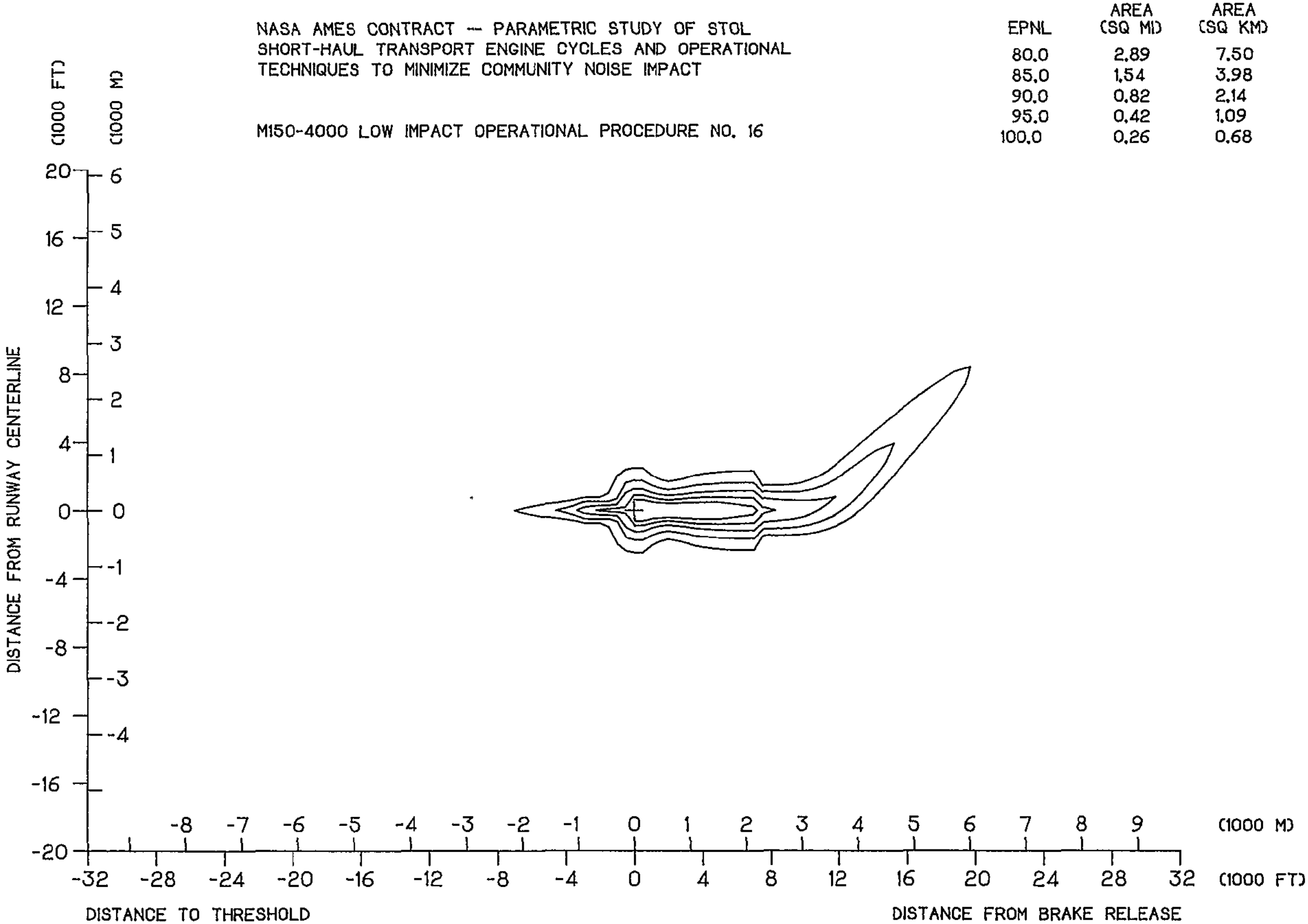

NASA AMES CONTRACT -- PARAMETRIC STUDY OF STOL
SHORT-HAUL TRANSPORT ENGINE CYCLES AND OPERATIONAL
TECHNIQUES TO MINIMIZE COMMUNITY NOISE IMPACT
M-150-4000 LOW IMPACT OPERATIONAL PROCEDURE NO. 12
EPNL
AREA (SQ MI)
AREA (SQ KM)
80.0 2.84 7.37
85.0 1.51 3.90
90.0 0.82 2.11
95.0 0.43 1.12
100.0 0.27 0.69
(1000 FT)
(1000 M)
DISTANCE FROM RUNWAY CENTERLINE
DISTANCE TO THRESHOLD
DISTANCE FROM BRAKE RELEASE

FIGURE C-34.



EPNL	AREA (SQ MI)	AREA (SQ KM)
80.0	2.89	7.50
85.0	1.54	3.98
90.0	0.82	2.14
95.0	0.42	1.09
100.0	0.26	0.68

FIGURE C-35.

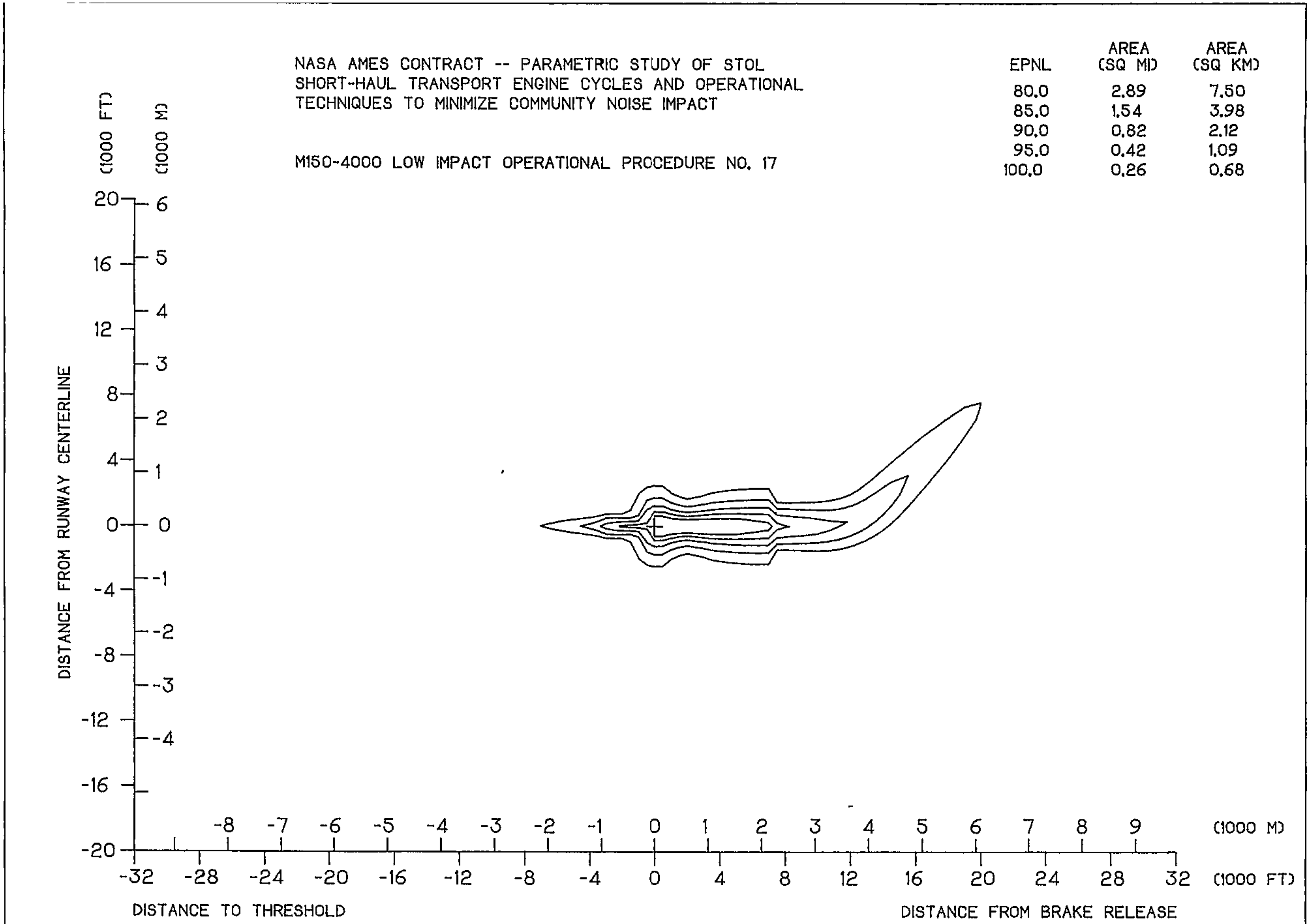

NASA AMES CONTRACT -- PARAMETRIC STUDY OF STOL
SHORT-HAUL TRANSPORT ENGINE CYCLES AND OPERATIONAL
TECHNIQUES TO MINIMIZE COMMUNITY NOISE IMPACT
M150-4000 LOW IMPACT OPERATIONAL PROCEDURE NO. 17
EPNL
AREA (SQ MI)
AREA (SQ KM)
80.0 2.89 7.50
85.0 1.54 3.98
90.0 0.82 2.12
95.0 0.42 1.09
100.0 0.26 0.68
(1000 FT)
(1000 M)
DISTANCE FROM RUNWAY CENTERLINE
20
16
12
8
4
0
-4
-8
-12
-16
-20
6
5
4
3
2
1
0
-1
-2
-3
-4
-8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9
(1000 M)
-32 -28 -24 -20 -16 -12 -8 -4 0 4 8 12 16 20 24 28 32
(1000 FT)
DISTANCE TO THRESHOLD
DISTANCE FROM BRAKE RELEASE

FIGURE C-36.

NASA AMES CONTRACT -- PARAMETRIC STUDY OF STOL SHORT-HAUL TRANSPORT ENGINE CYCLES AND OPERATIONAL TECHNIQUES TO MINIMIZE COMMUNITY NOISE IMPACT

M-150-4000 LOW IMPACT OPERATIONAL PROCEDURE NO. 20

EPNL	AREA (SQ MI)	AREA (SQ KM)
80.0	2.67	6.92
85.0	1.63	4.22
90.0	1.01	2.60
95.0	0.51	1.33
100.0		

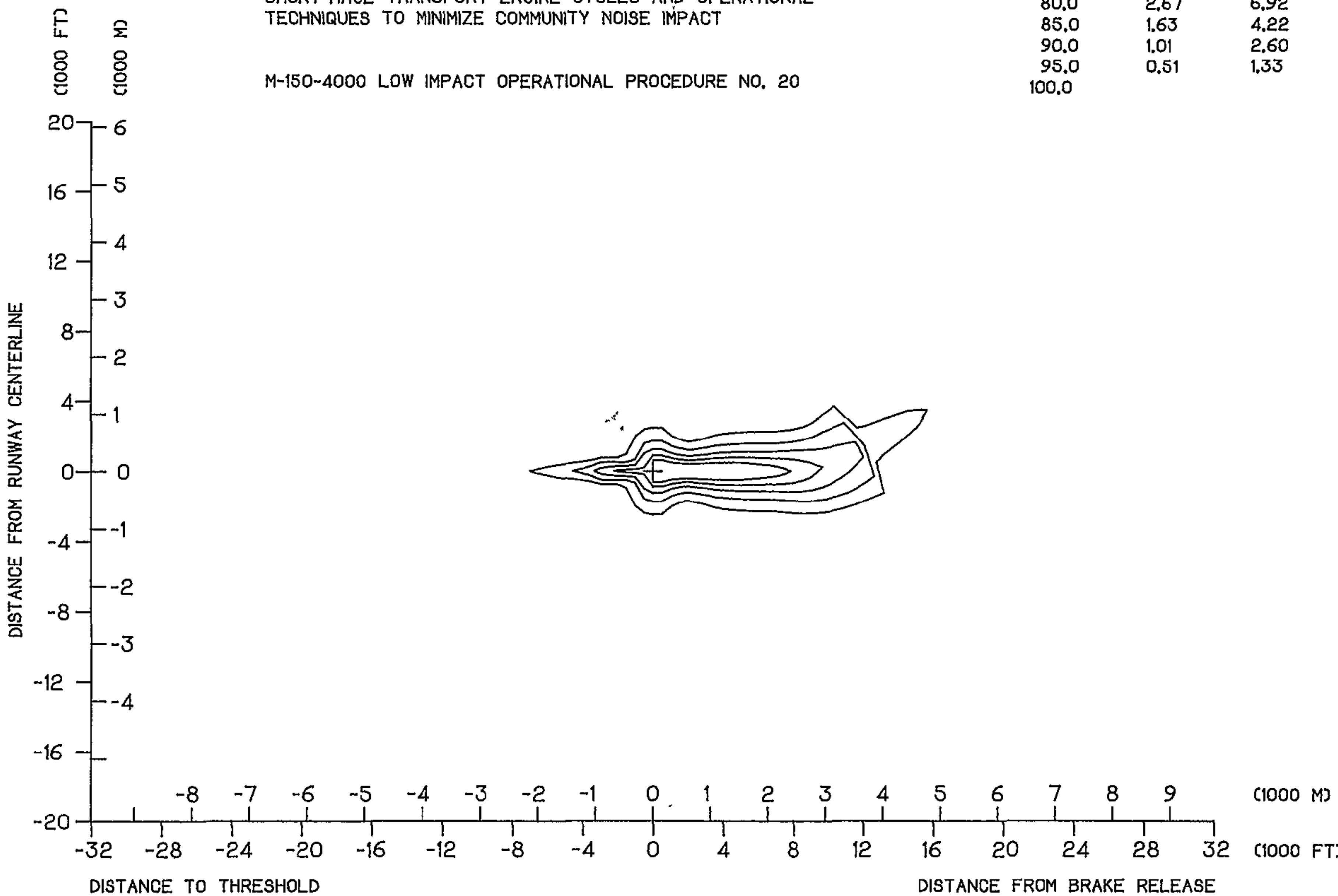


FIGURE C-37.

DOUGLAS AIRCRAFT COMPANY

3855 Lakewood Boulevard, Long Beach, California 90846 (213) 593 5511

MCDONNELL DOUGLAS
CORPORATION